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AUTOMATIC LAYOUT TECHNIQUES FOR THE GRAPHICAL EDITOR IN THE COMPUTER AIDED PROTOTYPING SYSTEM (CAPS)

by

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The Computer Aided Prototyping System (CAPS) is a systems engineering tool intended to make the iterative process of software development more efficient. The simplest way to input and modify a CAPS design is through the graphical editor. When a design is modified over and over, the resultant graphical representation can become difficult to comprehend. Trying to change the graphical representation by hand can be very tedious.

By adding automatic layout techniques to the graphical editor, this task is made easier for the user of the system. Automatic layout techniques for general graphs that maximize all of the aesthetic characteristics of a graph are not possible. One characteristic may conflict with another. By giving the user multiple layout algorithms that emphasis different characteristics over others, the user may choose between different layouts for the graphical representation.

Since CAPS was in the middle of a restructure and no graphical editor was available, automatic layout techniques were investigated using other graphical editors. Graphs with characteristics similar to a CAPS graph were input into the graphical editors and then the layout algorithms applied. The results of this assessment proved that the addition of automatic layout techniques to CAPS would improve performance. The library of layout algorithms will be incorporated into the new graphical editor in CAPS.

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AUTOMATIC LAYOUT TECHNIQUES FOR THE GRAPHICAL EDITOR IN THE COMPUTER AIDED PROTOTYPING SYSTEM (CAPS)

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ABSTRACT

The Computer Aided Prototyping System (CAPS) is a systems engineering tool intended to make the iterative process of software development more efficient. The simplest way to input and modify a CAPS design is through the graphical editor. When a design is modified over and over, the resultant graphical representation can become difficult to comprehend. Trying to change the graphical representation by hand can be very tedious.

By adding automatic layout techniques to the graphical editor, this task is made easier for the user of the system. Automatic layout techniques for general graphs that maximize all of the aesthetic characteristics of a graph are not possible. One characteristic may conflict with another. By giving the user multiple layout algorithms that emphasis different characteristics over others, the user may choose between different layouts for the graphical representation.

Since CAPS was in the middle of a restructure and no graphical editor was available, automatic layout techniques were investigated using other graphical editors. Graphs with characteristics similar to a CAPS graph were input into the graphical editors and then the layout algorithms applied. The results of this assessment proved that the addition of automatic layout techniques to CAPS would improve performance. The library of layout algorithms will be incorporated into the new graphical editor in CAPS.

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I. INTRODUCTION

A. GENERAL

The chore of programming a computer to perform a desired task has become increasingly difficult over the past few decades. The tasks that computer programmers are asked to complete are much more complex and difficult than previously attempted. However, the tools that computer programmers have utilized to perform these tasks have not enabled these systems to be easily built and maintained.

The trend in the field of software engineering is towards automated tools that handle the more tedious components of the software engineering process. This allows the computer programmer to apply more resources to the creative process by trying different approaches without investing too many assets up front.

The Computer Aided Prototyping System (CAPS) is an integrated set of tools that allows a software engineer to design large software systems and test their design prior to implementation. The software engineer can start designing a system with CAPS using a top down approach. At each level of detail, the system can be tested to ensure that the system's performance is within the parameters of the desired end product.

To ease the process, CAPS has a graphical interface for the design process. Each operator can be laid out in the graphical display. These operators are connected to each other with directed lines that represent streams. Each operator can be subdivided into simpler operators until all the operators are atomic operators. Each operator can have performance constraints associated with it. CAPS can test that these constraints are not violated by the overall design. If a violation occurs, the design can be modified until the desired system specifications are reached.

B. PROBLEM STATEMENT

This research is a revision of the work on the graphical editor of CAPS. The current graphical editor has no automated layout capabilities. The program graph can become convoluted after many edits. Automated layout techniques will be investigated for use in the CAPS graphical editor that will minimize such attributes as crossing lines and spacing.

By adding automatic layout techniques to the graphical editor, designer/programmer productivity is gained by helping them get the job done faster. Further, the resulting program graphs will be easier to comprehend.

C. SCOPE

The scope of this thesis will deal with the capabilities of layout techniques for directed graphs while simultaneously analyzing the unique needs of the graphical editor in CAPS. Once both are completed, findings will be used to build an automated layout function that will meet the needs of the CAPS in the most user friendly means available.

This thesis contains three primary products. The first is a survey of current automated layout algorithms for graphs. The second is an evaluation of the properties of a common program graph in CAPS. The third is the implementation of automated layout algorithms for the CAPS graphical editor.

II. BACKGROUND KNOWLEDGE

A. GENERAL

The Computer Aided Prototyping System (CAPS) is a software-engineering tool designed to take the drudgery out of prototyping systems. A software developer can design a software system, test the design, and add timing requirements. Most projects become an iterative process of re-visiting the design, making the necessary changes to fix problems, and then testing the new design.

After a few iterations, the graphical display of the prototyped system can become very difficult to understand, since the graphical display requires the user to layout the design. Fixing the design layout by hand requires some time. The layout editor in CAPS is also rather slow and plodding for the user. By providing automatic layout techniques to the user, the chore of laying out the design in a more coherent manner is lessened.

B. GRAPH CHARACTERISTICS

All graphs have different characteristics. By testing a graph for these characteristics, a graph can be categorized into different graph categories. These graph categories include trees, planar undirected graphs, planar directed graphs, general undirected graphs, general directed graphs, etc.

Graphs can be trees if no cycles exist. They can be planar if the display of the graph is meant to be two-dimensional.

A general graph can be displayed with any-dimensional perspective. The edges connecting the graphs can also differ in category. In general, directed graphs have an edge with at least one arrow signifying direction. Undirected graphs have no arrows and there is no restriction on the direction. Figure 2.1 shows several different graphs with differing characteristics.

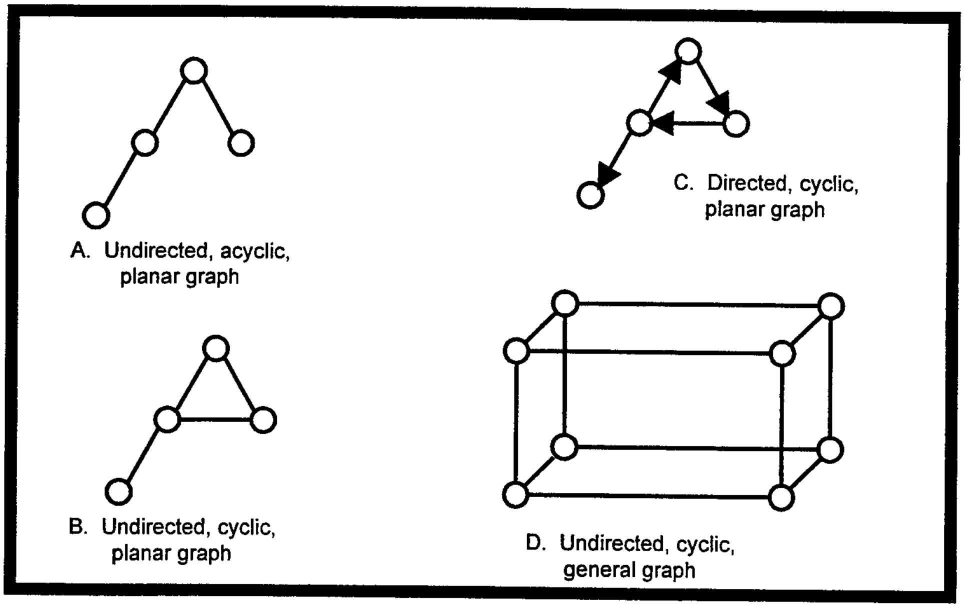


Figure 2.1: Different characteristics of graphs

Another characteristic important in laying a graph out is whether polyline drawings are permitted. Polyline drawings allow for bends in an edge. Straight-line drawings only allow for straight-lines to be drawn between vertices. Figure 2.2 demonstrates this problem.

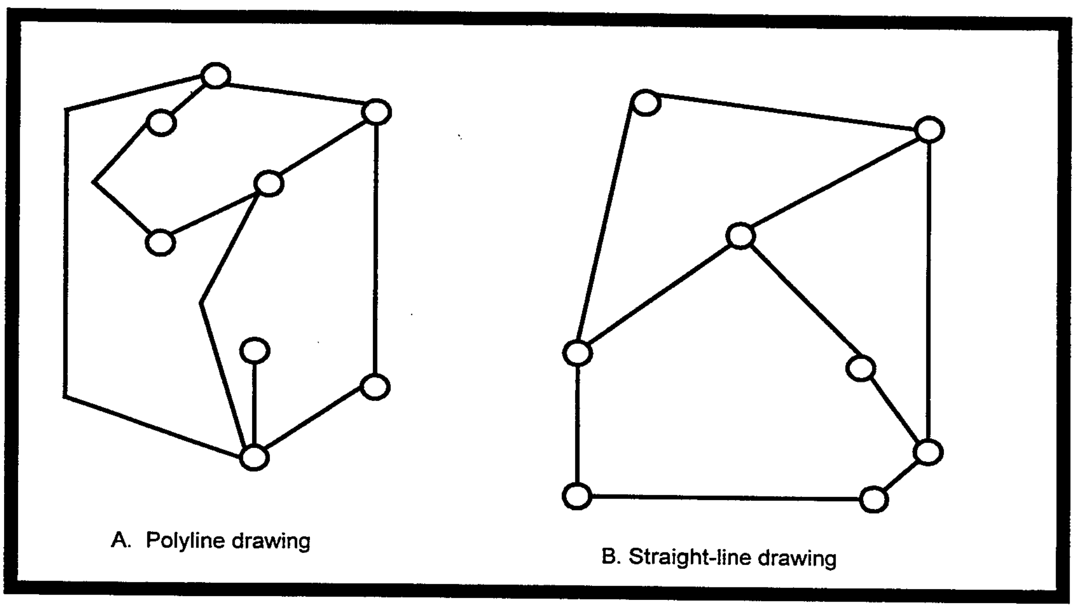


Figure 2.2: Polyline drawing vs Straight-line drawing

An orthogonal drawing maps each edge into a chain of horizontal and vertical segments. This produces a boxy looking graph. Figure 2.3 gives an example of an orthogonal graph.

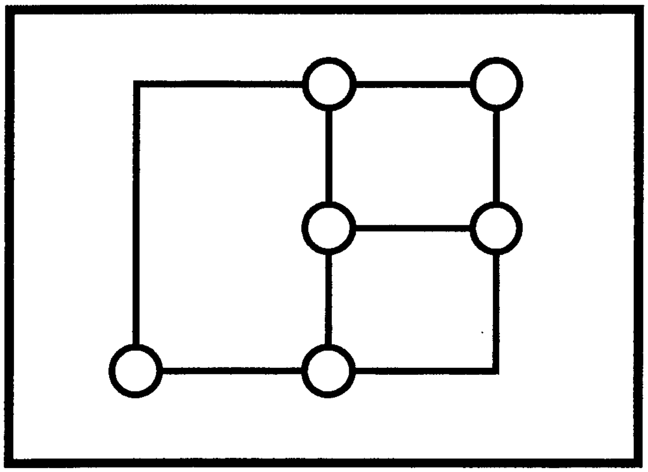


Figure 2.3: Orthogonal graph

C. AUTOMATIC LAYOUT TECHNIQUES

Automated layout techniques for a graph is an ongoing research area. Laying out a generic graph optimally is considered a NP Complete task. However, there exist algorithms that can approximate an optimal solution. By having the computer do most of the tedious work, a user optimize the layout with minor adjustments.

Graph layout techniques can be written to layout a generic graph or a subset of the set of all graphs. A tree graph would use an algorithm whose sole purpose is to optimize the layout of trees. This algorithm would not work for graphs that have cycles. Another class of algorithms would be used for graphs with cycles.

An optimal presentation of a generic graph is based on aesthetic criteria. Aesthetic criteria attempt to characterize readability by means of general optimization goals. These goals consist of:

1. **Minimize crossing**

2. **Minimize area**

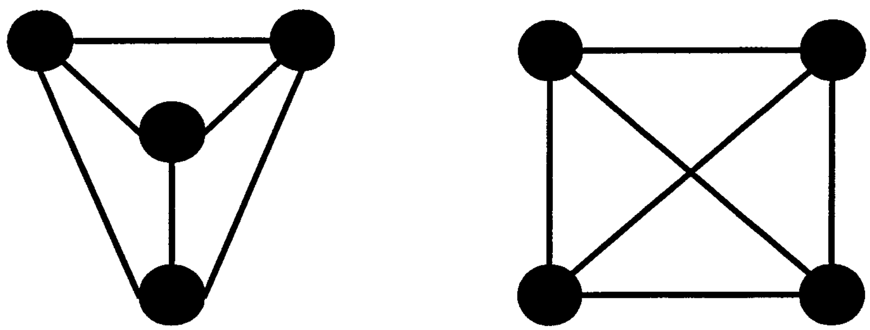
3. **Minimize bends (in orthogonal drawings)**

4. **Minimize slopes (in polyline drawings)**

5. **Maximize smallest slope**

6. **Maximize display of symmetries**

In general, one cannot simultaneously optimize two aesthetic criteria. A simple example of this problem can be shown in Figure 2.4. A simple graph of four nodes and six links is displayed with different criteria. Since these criteria cannot optimize all aesthetic criteria, a set of constraints is usually provided as additional input to a graph drawing algorithm. These constraints specify which criteria are more important for the desired layout.



A. Minimize crossing B. Maximize symmetries

Figure 2.4: Differences in optimization with different criteria.

By allowing a blending of different criteria the user can automatically change the appearance of the display by playing with the constraints. This leads to many complexity issues. Testing planarity takes linear time. Testing upward planarity is NP-hard. Minimizing crossing is NP-hard. All of these constraints add to the complexity of the algorithms. They also add to the time taken to compute a layout.

III. ANALYSIS OF AUTOMATED LAYOUT TECHNIQUES

A. GENERAL

Numerous algorithms exist for automatically laying out graphs. Since the optimal layout for a graph is a NP Complete problem, these algorithms are only approximations to an optimal layout. Almost every algorithm returns a different solution to the question for a specific graph. Some algorithms give different answers when called repeatedly. Usually, a library of algorithms are given to the user to interactively select a layout by running different algorithms until he finds a layout that is aesthetically pleasing and more coherent.

B. GENERAL TECHNIQUES

In general, all algorithmic approaches to laying out a graph in an aesthetically pleasing manner can be broken down into categories. Inside each category there are many variations of the general theme. This section will outline the general themes of these main categories.

Trees or rooted trees are often used to represent hierarchies such as family trees, organizational charts, and search trees. Planar straight-line drawings and orthogonal polyline drawings are commonly used to represent rooted trees. In general, vertices are placed along horizontal lines according to their level. There is a minimum separation distance between two consecutive vertices on the same level. The width of the drawing is as small as possible. Also, for binary trees, left and right children of each vertex are placed to the left and right of the vertex, respectively.

In an inclusion representation of a tree, boxes represent nodes and parent-child relationships are represented by inclusion of one box in another. The tip-over convention is similar to the classical tree graph, however, children of some nodes may be arranged vertically rather than horizontally.

Free trees do not represent hierarchies and have no specific root. Selecting at random a root and then applying an algorithm for a rooted tree works adequately.

Straight-line drawing calls for minimizing crossing of lines in a general graph while minimizing the space required to display the graph and using only straight lines between edges, no polylines. The best approaches to this problem, to date, are heuristic based on a physical model.

The spring embedder algorithm takes such an approach. The drawing process is to simulate a mechanical system, where vertices are replaced by rings, and edges are replaced by springs. The springs attract the rings if they are too far apart, and repel them if they are too close. Variations to this model modify the energy function of the springs by criteria other than just distance.

Planarization involves ensuring that a general graph is planar. If not, it attempts to planarize the graph. This allows many techniques that have been developed for planar graphs to be used.

The most common planarization operation is edge deletion. The smallest set of edges whose deletion yields a planar graph is found. This is equivalent to finding a planar subgraph with a large number of edges. Most of the algorithms that use edge deletion use different approaches for finding a maximum planar subgraph.

Another technique for planarization is splitting. The splitting operation is to make two copies of a vertex and share the neighbors between the two copies. Algorithms that use splitting try to optimize the finding of a minimum splitting sequence.

C. ALGORITHM SEARCH

Relatively little information on graph layout algorithms is available. Only through a search on the Internet was the needed information found. There exist a few home pages on the Internet that deal with automatic layout algorithms. Books on the subject are just emerging.

D. THE GRAPH DRAWING SERVER (GDS)

The graph drawing server is located via Dr. Tamassia's home page at http://www.cs.brown.edu/people/rt. This server is a collection of graph drawing algorithms that can be access via a Java applet that can run locally. Basically, the user interface is in Java, and the algorithms are running on the host machine. This doesn't allow for easy inclusion, but it does provide an excellent vehicle to ascertain the abilities of graph drawing algorithms. The following is an explanation of the algorithms available in GDS.

1. Giotto.

Giotto constructs an orthogonal drawing of a graph using a network flow method in the orthogonalization phase to obtain the minimum number of bends. Giotto accepts a general multigraph as input and augments it to create a connected graph. The connected graph is planarized. Vertices with degree greater than four are expanded into rectangular symbols, which are viewed as cycles of degree four to yield a graph with maximum degree four. Finally, the graph is passed through orthogonalization and compaction phases. The time complexity is O((N+C)^2log(N+C)) where N is the number of vertices in the input graph and C is the number of crossings in the drawing constructed [TAMASSIA97].

2. Giotto with labels.

This is a version of Giotto, which draws each vertex as an expanded box large enough to fit its label.

3. Bend-Stretch.

Bend-Stretch has the same three steps – planarization, orthogonalization, and compaction – as Giotto, and differs only in the method used in the orthogonalization step. It adopts the "bend-stretching" heuristic of the Tamassia and Tollis that only guarantees a constant number of bends on each edge, but runs in linear time. The time complexity is O((N+C)^2log(N+C)) where N is the number of vertices in the input graph and C is the number of crossings in the drawing constructed [TAMASSIA97].

4. Pairs.

Pairs accepts a general multigraph as input, which is augmented to produce a connected graph and then further augmented to produce a biconnected graph. This biconnected graph is then drawn according to its orthogonal drawing algorithm. The edges added by the augmentation steps are not displayed in the final drawing. The time complexity is O((N+M)log(N+M)) where N is the number of vertices in the input graph and M is the number of edges [TAMASSIA97].

5. Series Parallel Drawing.

This algorithm recognizes a series parallel digraph and constructs an upward drawing of it using the delta-drawing algorithm. This is an implementation of "The Recognition of Series Parallel Digraphs" by Valdes, Tarjan, and Lawler. Any graph is accepted as input; an error message will be displayed if it is not a series parallel digraph [TAMASSIA97].

6. Sugiyama.

Sugiyama constructs a hierarchical drawing of a directed graph according to its algorithm. If the input graph is not directed, it is first converted to a directed graph.

The algorithm uses a three-step process: first, in a layering step, it assigns vertices to horizontal layers. Next, in a crossing-minimization step, it permutes the vertices within the same layer to reduce edge-crossings. Finally, in a bend-reduction step, it readjusts the position of vertices within each layer to reduce edge-bends [TAMASSIA97].

7. Column.

Column is similar to Pairs and differs from it only in the method to optimize the number of bends, rows, and columns used in the drawing, once an st-numbering has been computed. The method used is the one of Biedl and Kant. The time complexity is O(N+M) where N is the number of vertices in the input graph and M is the number of edges [TAMASSIA97].

8. Ortho Upward.

Ortho Upward is an algorithm that produces a straight-line orthogonal upward drawing of a binary tree.

9. Ortho Non-Upward.

Ortho Non-Upward produces a straight-line orthogonal (non-upward) drawing of a binary tree.

10. Planarizer.

Planarizer is the planarization step of Giotto and constructs a planar embedding of the input graph by replacing edge crossing with fictitious vertices. It has time complexity O((N+C)^2log(N+C)) where N is the number of vertices in the input graph and C is the number of crossings in the drawing constructed [TAMASSIA97].

E. GRAPHLET

Graphlet is a toolkit for graph drawing algorithms. Most applications start with an abstract graph structure that has no coordinates. Arranging the nodes and edges in a nice fashion is a tedious process for humans. Graph drawing algorithms help users to draw graphs. Graphlet's editor toolkit is implemented with C++, LEDA, Tcl/Tk and Graphscript. Below are some outputs of Graphlet [HIMSOLT97].

Graphlet is available on multiple machines and operating systems. It is available on a PC for Windows or Linux. It runs on Sun's running SunOS or Solaris. Graphlet also runs on Hewlett Packard (HP)'s running HP-UX.

With the diversity of platforms, its intuitive user interface, and the source being C++ Graphlet was chosen to display the graphs since the graphical editor was not available.

1. Random Layout.

Random Layout generates random [x,y] positions for the nodes of a graph. It is useful when evaluating different graph algorithms.

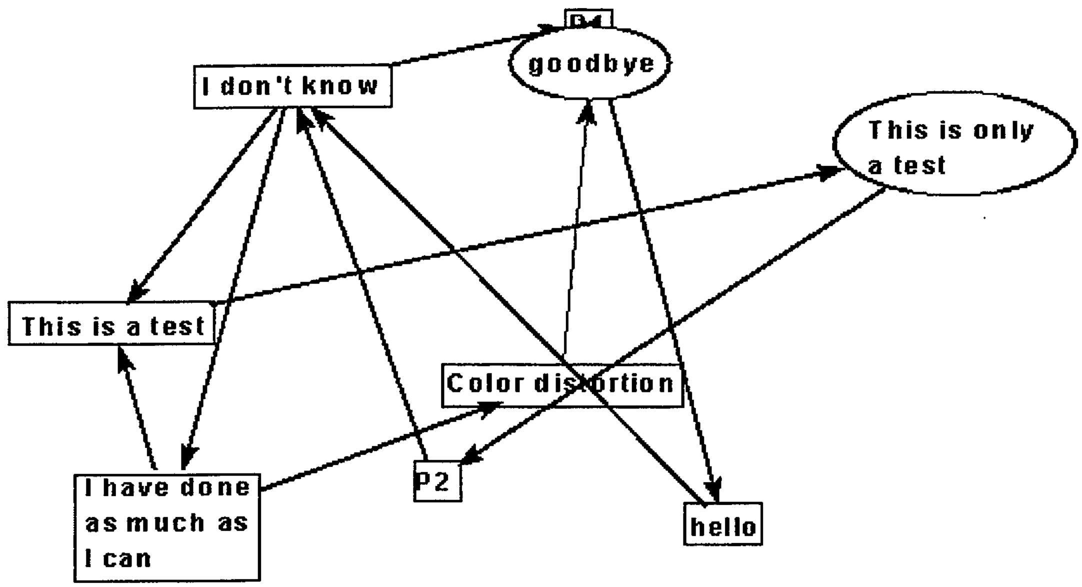


Figure 3.1: Random Layout

2. Spring Embedder with Constraints

Spring Embedder with Constraints is a straight line layout algorithm that tries to maximize space, edge crossing, and angular resolution.

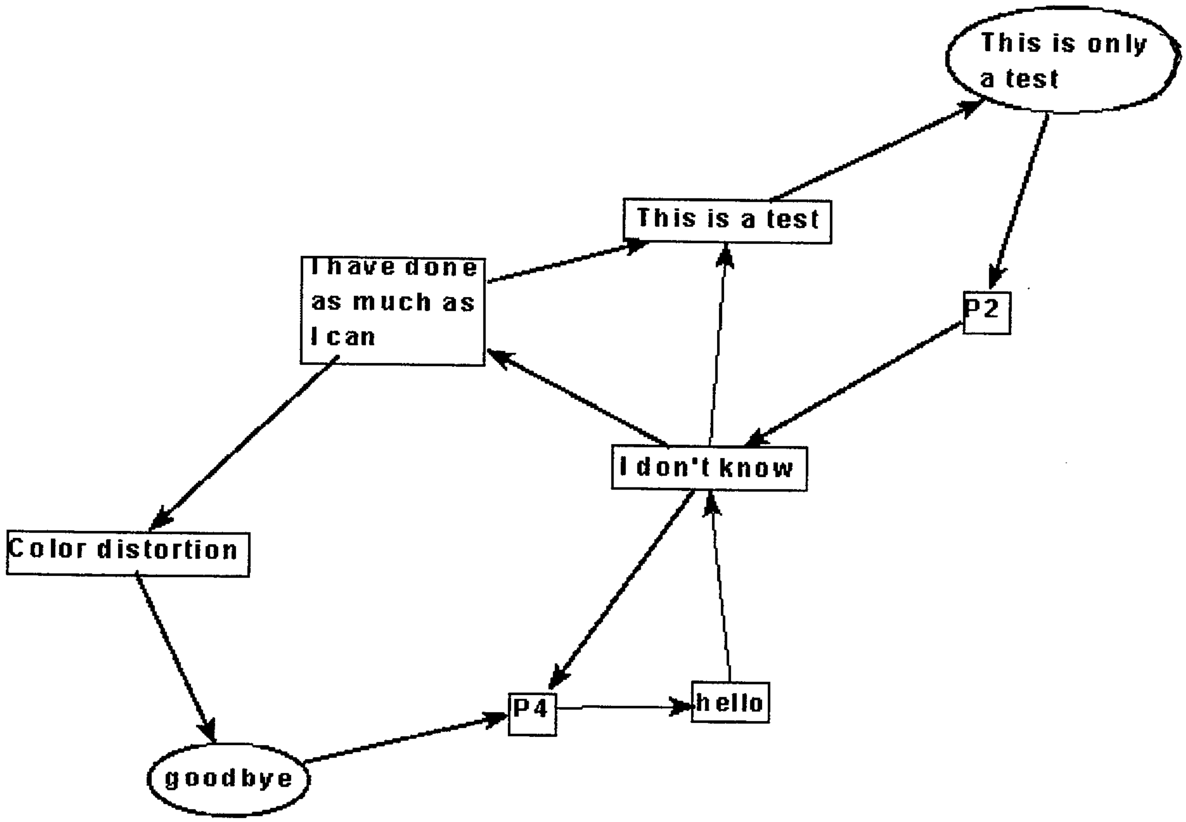


Figure 3.2: Spring Embedder with Constraints

3. Iterative Constraint Spring Embedder

Iterative Constraint Spring Embedder is similar to Spring Embedder with Constraints. However, it iterates the method to produce an orthogonal graph.

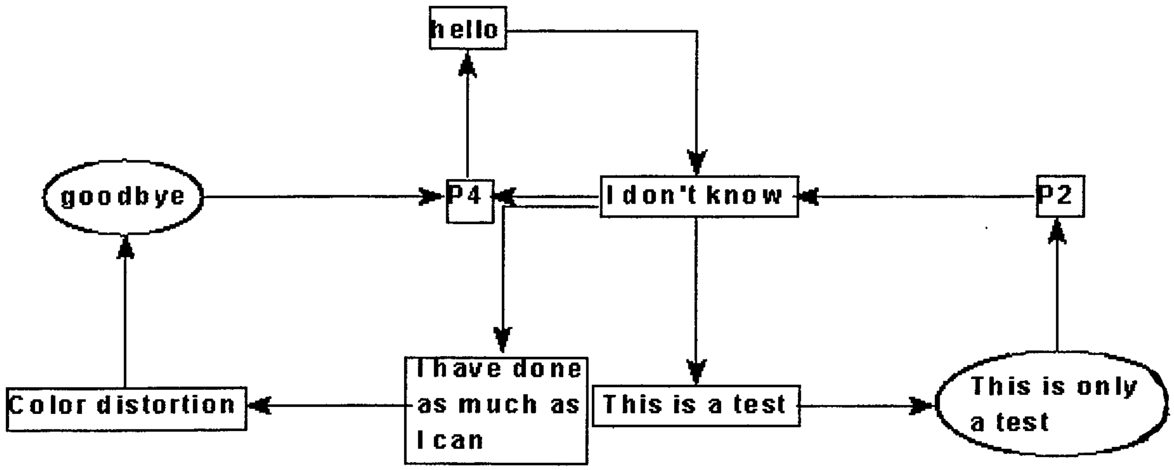


Figure 3.3: Interative Constraint Spring Embedder

4. Spring Embedder (GEM)

GEM is another Spring Embedder. It seeks to minimize space and edge crossing.

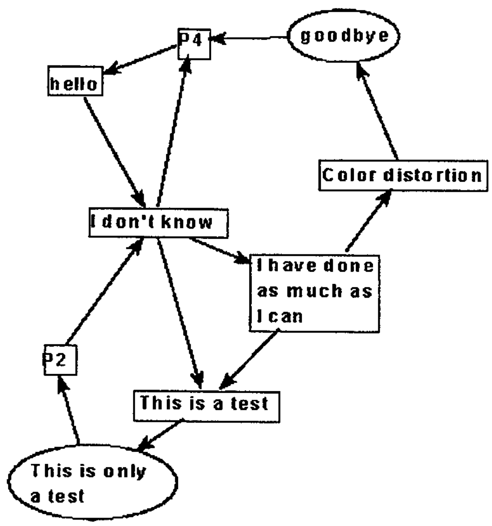


Figure 3.4: Spring Embedder (GEM)

5. Spring Embedder (Kamada)

Kamada is another variation of the Spring Embedder approach.

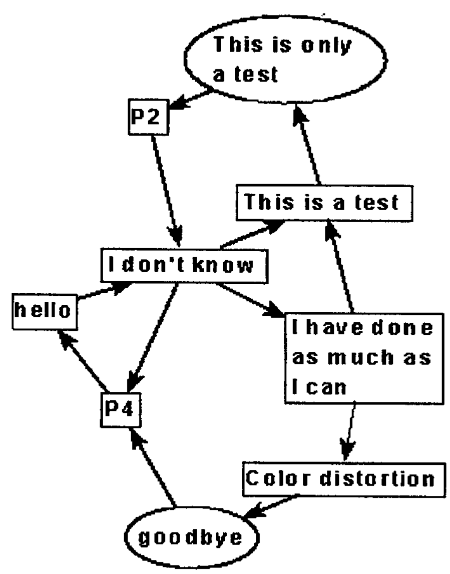


Figure 3.5: Spring Embedder (Kamada)

6. General Graphs (Tunkelang)

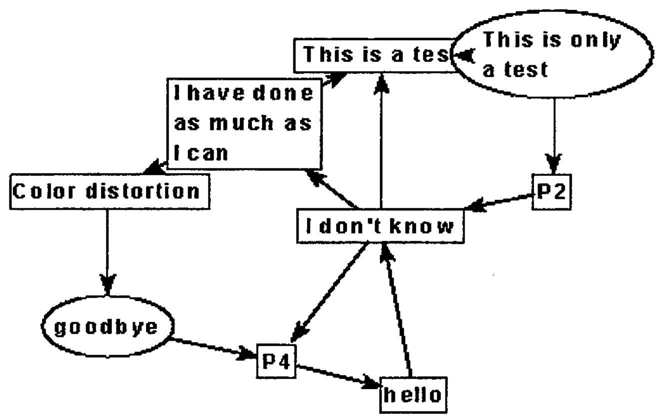


Figure 3.6: General Graphs (Tunkelang)

7. DAG

DAG is a very interesting drawing algorithm. It allows for multiple line segments for edges. It also tries to orient the graph to flow down.

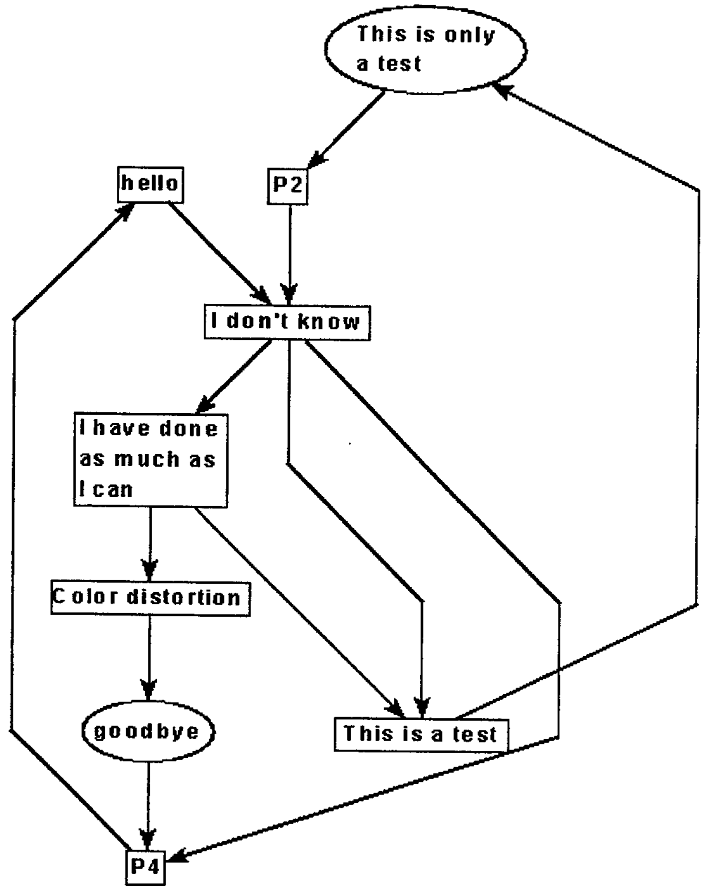


Figure 3.7: DAG

IV. ANALYSIS OF CAPS GRAPHICAL EDITOR

A. GENERAL

The Computer Aided Prototyping System (CAPS) is a software-engineering tool designed to take the drudgery out of prototyping systems. A software developer can design a software system, test the design, and add timing requirements. Most projects become an iterative process of re-visiting the design, making the necessary changes to fix problems, and then testing the new design.

After a few iterations, the graphical display of the prototyped system can become very difficult to understand, since the graphical display requires the user to layout the design. Fixing the design layout by hand is tedious. In the last release of CAPS, Version 1.1, the graphical editor was almost impossible to use when changing the layout to a more meaningful form. The refresh rates made moving a node so cumbersome that the software engineer often didn't want to update a designs layout.

B. CAPS CHARACTERISTICS

The set of graphs that CAPS uses is a subset of all graphs. The following are characteristics that CAPS graphs will have. These characteristics are important in selecting layout algorithms. The most important distinction from the set of all graphs to the set of all graphs that CAPS can create is that all CAPS graphs are directed graphs.

The edges in CAPS represent streams of data. They always flow from a source to a destination. The edges are drawn with arrows to depict direction of the data flow. These edges are splines. Text on the edge represents the variable name in the CAPS PSDL program. CAPS displays one edge per stream. If a call from one object to another requires ten streams, then ten edges are drawn with CAPS graphical editor.

Nodes are represented by two classes of objects with each having a subclass resulting in four distinct node representations. Operators are represented with an oval and terminators are represented with a rectangle. Each of these types can have subgraphs.

This is displayed by putting a double oval or rectangle instead of a single line. Basically, the object is halloed if a subgraph exists. Nodes can be color coded to further differentiate the class.

V. FUTURE REQUIREMENTS OF AUTOMATED LAYOUT TECHNIQUES FOR DIRECTED GRAPHS

A. GENERAL

Research in the area of automated layout techniques for a directed graph is going on in the world, today. Since graphs allow users to visualize many different problems, the ability to display these graphs in an aesthetically pleasing manner is highly desirable. Every year, since 1992, an annual workshop on graph drawing [GD 92, 93, 94, 95, 96, 97] is held to improve the capabilities of existing and new algorithms.

B. RESEARCH AREAS

There exist many research areas in the field of graph drawing. Because the problem in general is NP-Complete, practical algorithms can only be approximations of the ideal solution. Also, the ideal solution can vary depending on the problem area being visualized.

Much research is being conducted in general areas of graph drawing and in application specific areas. Some of the areas that still require future research that will be of particular interest for CAPS are detailed below.

1. Performance Bounds for Planarization.

Although crossing minimization is a fundamental issue, non-trivial performance bounds have not been found for any heuristic. A guaranteed heuristic would be very important both for aesthetic graph drawing and VLSI layout [TAMASSIA94].

2. Simple Planarity Testing.

The known planarity algorithms that achieve linear time complexity are all difficult to understand and implement. This is a serious limitation for their use in practical systems. A simple and efficient algorithm for testing the planarity of a graph and constructing planar representations would be a significant contribution [TAMASSIA94].

3. General Strategy for Straight-Line Drawings.

General strategies have been successfully developed for hierarchical drawings and orthogonal grid drawings. These techniques take several aesthetics into account. The simplicity of straight-line drawing is very appealing, and a general straight-line drawing technique would find immediate applications [TAMASSIA94].

4. Dynamic Drawing Algorithms.

Several graph manipulation systems allow the user to interactively modify a graph by inserting and deleting vertices and edges. Data structures that allow for fast restructuring of the drawing would be very useful. The time needed to re-compute the layout must be small to keep the system from becoming cumbersome, since the algorithm would be called every time an update occurred [TAMASSIA94].

5. Complexity of Bend Minimization.

Several issues on the computational complexity of minimizing bends in planar orthogonal drawings are open. If the embedding is fixed, bend minimization can be done in time O(n^2logn). It would be interesting to improve on the sequential complexity and to develop a fast parallel algorithm for the fixed-embedding problem [TAMASSIA94].

6. Angular Resolution of Planar Straight-Line Drawings.

The angular resolution of a planar straight-line drawing is the minimum angle formed by two edges incident on the same vertex. It has been shown that a planar graph of degree d has a drawing with angular resolution upper bound of O(1/d) [TAMASSIA94].

VI. NEW AUTOMATED LAYOUT TECHNIQUES FOR CAPS DESIGN AND IMPLEMENTATION

A. GENERAL

The general idea is to add automated layout techniques to the CAPS graphical editor. However, this is easier said than done. Automated techniques for laying out a graph are really just estimates of a nice layout. A user will still have to make minor adjustments to the graph to fix any minor layout problems. Also, there exist many layout techniques that work best depending on the how the user views certain aesthetic characteristics and the type of graph being displayed.

B. CURRENT PROBLEMS

There are problems related to design and implementation of automated layout techniques for the CAPS graphical editor. The first problem is that the CAPS system is in a state of transition. The PSDL editor is being re-written to use a new PSDL data type. There doesn't exist any graphical editor for the new PSDL data type. Secondly, the graph part of a PSDL data type is private. Without either modifying the PSDL data type to export its layout or making the graph functions in the PSDL data type public, there would be no way to implement new techniques via the PSDL data type.

The use of twin lines in CAPS also creates aesthetic problems. Twin lines are defined as an edge with the same start node and finish node with equal direction. By allowing the user to collapse twin lines for aesthetic reasons, a more easily understood graph is presented. Figure 6.1 demonstrates this point nicely.

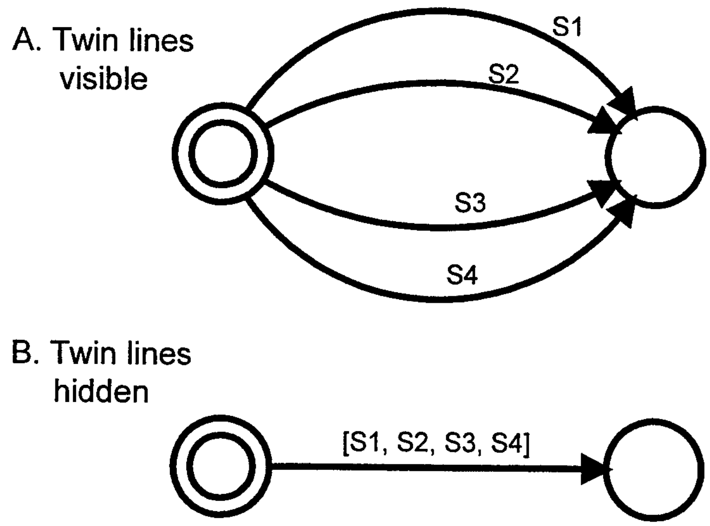


Figure 6.1: Hiding twin lines

C. DESIGN OF TEST SYSTEM

The design of this implementation is not optimal. However, given the availablity of the graphical editor in the CAPS system it represents a valid workaround.

Basically, the design is to hook two systems together via some middleware. Since the CAPS system outputs a PSDL file, the file could be read and the graph extracted. This extracted graph would then be fed into a graphical editor that could display the graph. The user interface of this graphical editor would allow the user to run different algorithms and modify the parameters of these algorithms. Figure 6.2 gives a graphical view of this design.

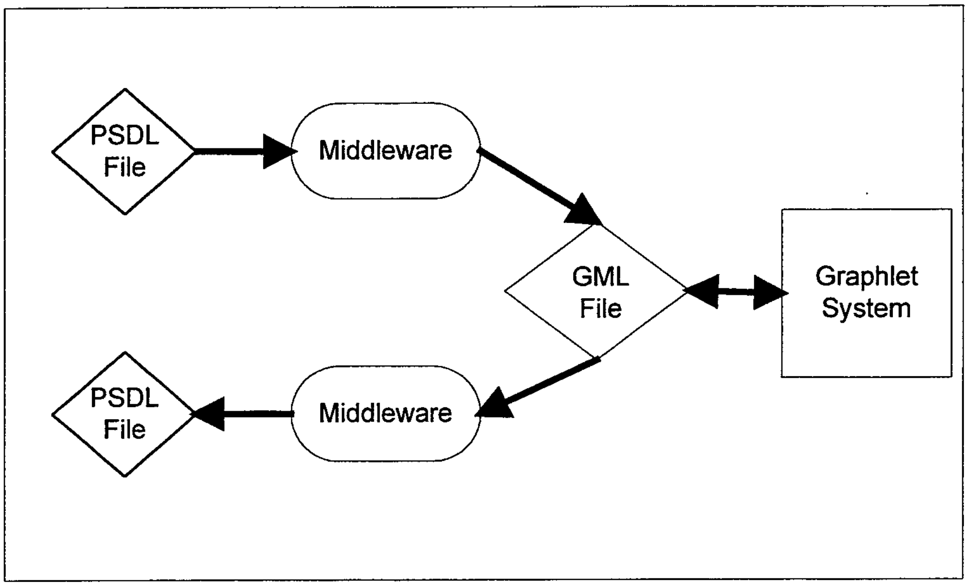


Figure 6.2: Design of test system

D. IMPLEMENTATION OF TEST SYSTEM

1. PSDL Data Type.

The PSDL data type is stored in a PSDL file. These files usually end with the suffix ".psdl". Since the graph portion of the PSDL data type is private, one must access the graph from a program that uses the PSDL data type without modifying the PSDL data type. Public operators available to a user of the PSDL data type do not allow access of the graph, therefor only by modifying the PSDL data type can new capabilities be added.

2. Middleware.

The middleware is a program that takes a PSDL file and exports a GML file or takes a GML file and updates a PSDL file with the GML file. An example would be the following commands:

% middleware –p <psdl file> <gml file>

% middleware –g <psdl file> <gml file>

3. GML File.

The GML File format is a common format to represent a graph used in many graph theory systems. By using this file format, multiple systems could be brought to the table to aid in the drawing of graphs. Also, new algorithms could more easily be integrated into the system. The complete file format for GML is located in document [HIMSOLT96].

4. Graphlet system.

The Graphlet system is freeware that allows a GML file to be read into the system. After the graph is input, the user can choose various algorithms, make slight modifications to the variables in each algorithm. A user can then make minor adjustments to the graph. The new graph can then be saved with the new layout [HIMSOLT97].

E. DESIGN OF REAL SYSTEM

In the last month of this writing, a new version of the CAPS graphical editor has been available. Since the ideal approach is to connect the layout algorithms directly to the graphical editor, the design has changed. Figure 6.3 gives a graphical view of the design for this implementation.

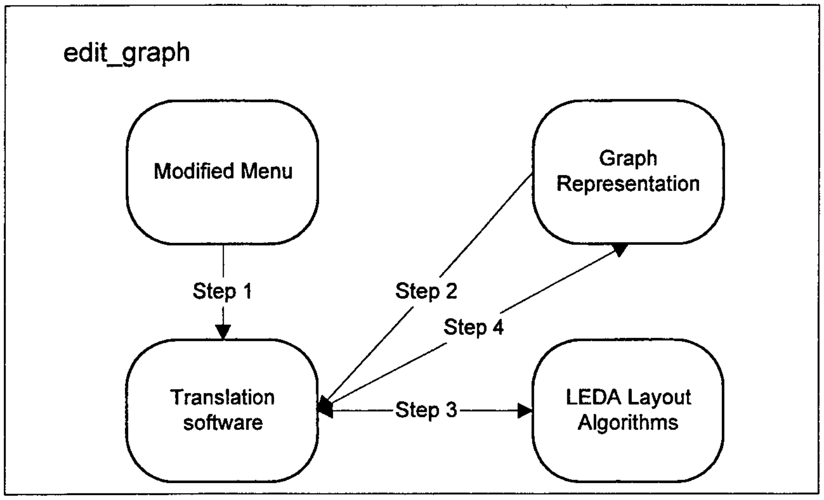


Figure 6.3: Design of REAL system

F. IMPLEMENTATION OF REAL SYSTEM

The implementation of the real system design consisted of porting the LEDA libraries to SunOS 4.1.3. After this was accomplished, the C++ LEDA libraries could be linked with the edit_graph program. Edit_graph is the executable program for the graphical editor.

The actual linking proved to be more complex than anticipated. CAPS actually uses different compilers for different pieces of the system. It is mostly a mixture of Ada95, C, and C++. LEDA actually needs to be compiled with a newer version of the GNU C++ compiler that CAPS does. In order to link the software, you need to use the linker in the newer version of the GNU C++ compiler.

Two parts of the edit_graph need to be modified to use the layout algorithms in LEDA. The first part deals with adding menu items to the system that allow a operator to invoke different algorithms. The second half deals with converting the PSDL data type representation of a graph to a LEDA representation and vis versa.

VII. CONCLUSION AND FUTURE RESEARCH

A. CONCLUSION

The need for automated layout techniques in CAPS is a very real one. These techniques allow a user to clean up the mess associated with iterative edits of the graph. The real place to put these algorithms is inside the graphical editor of the CAPS system. They should be initiated only by user interaction.

Since the graphical editor of the CAPS system was not available for the new PSDL data type, this could not be done. Instead, middleware was developed to allow the two systems to work together.

The graph part of the PSDL data type should use a standard format consistent with the graphing community. This would allow for easy synchronization with leading researchers in topology.

B. FUTURE RESEARCH

Future research needs to be done on the automated layout of graphs that does a better job of placing edge labels. This problem has not been addressed in much detail to date. Currently, most algorithms do reasonably well laying out the nodes, node labels, and edges. Once these algorithms are finished, they could be modified to handle edge labels better. CAPS graphs contain edge labels, operator labels, and maximum execution time (MET) labels. Optimizing the layout with all of these objects would increase the complexity of the algorithm.

The use of twin lines in the CAPS system can become very cluttered in the graphical display. Allowing the user to toggle the twins to visible or hidden would greatly improve the aesthetics of the graph.

The use of splines for edges needs to be studied. Straight line drawing and polyline drawing of edges is the norm. Splines are similar to polyline drawings with the corners rounded. If splines do not aid in the comprehension of the graph, then they

should be replaced with polylines. Drawing a polyline is much faster than drawing a spline. Regardless, the user should be able to choose between splines, straight lines, and polylines to represent edges.

C. CAPS IMPROVEMENT

1. Spline Drawing

Splines are currently drawn one point at a time. The actual algorithm is very inefficient. It doesn't take into account the resolution of the system's display. Duplicate points are very possible. This means that the same point will be drawn more than once. By computing all the points first, then removing duplicate point, a faster algorithm will result.

Streams are displayed as bold splines. For each of the points in the spline, eight additional points are drawn. Basically, all of the original point's neighbors are also drawn point by point. By drawing the bold spline with a filled square of 3x3 pixels instead of 9 separate, one pixel draws, the algorithm would be more efficient.

2. File format

The current format for the PSDL graph is unique to CAPS. If more conventional graph representations were incorporated, then PSDL graphs could be exported to other graph systems. This would also allow for improvements to CAPS graphical editor with minimal changes by using a standard commonly recognized in the graphing community.

APPENDIX A: LEDA LICENSE INFORMATION

A. LEDA LICENSE

You are installing the RESEARCH version (LEDA-R) of LEDA that can be used free of charge for academic research and teaching.

FOR ANY COMMERCIAL USE OF THIS SOFTWARE A LICENSE IS REQUIRED. ANY KIND OF USE BY A COMPANY OR OTHER NON-ACADEMIC INSTITUTION IS CONSIDERED TO BE COMMERCIAL USE. YOU ARE BREAKING A LAW WHEN USING LEDA COMMERCIALLY WITHOUT OWNING A LICENSE.

These terms are valid for all LEDA versions following version 3.0. For more information about the license terms please contact:

LEDA Software GmbH
Postfach 151101
66041 Saarbruecken
Germany
email:leda@mpi-sb.mpg.de
fax: +49 681 842502

You are allowed to continue with the installation of LEDA only if you are owner of a valid license or if you intend to use LEDA for academic research or teaching. Otherwise, you must stop the installation now.

B. LEDA INFORMATION

1. LEDA-R-3.5.1

The new LEDA version available on our ftp server is "LEDA-R-3.5.1". The "R" stands for research and has been added to make it distinguishable from the commercial version distributed by LEDA Software GmbH. Please read the Changes files for information about new features and other changes.

LEDA-R-3.5.1 can be used free of charge in academic research and teaching. Licenses for the commercial version "LEDA 3.5.1" are distributed by the LEDA Software GmbH.

2. Differences between LEDA and LEDA-R

The only difference between LEDA-R and LEDA is that the research version may contain additional data types, algorithms or other features which are:

- experimental (not tested enough or not working on all platforms)
- of interest only for particular research
- temporary (may be removed or changed in future versions)

The commercial version will never contain data types, algorithms or features of this kind. It is supposed to stay backward consistent in the sense that old programs should work with new versions of LEDA.

3. Who needs a license?

- Every organization that uses LEDA and is not an academic research institute or school.

- Everyone who sells programs that are developed using LEDA.

- Everyone who delivers programs that are developed using LEDA to non-academic organizations.

Holders of a licence for the commercial version are free to also use the research version for commercial use.

Please write to leda@mpi-sb.mpg.de if you want to
* send bug reports or suggestions
* get information on the commerical license
* be on our mailing list

Subscribe to the LEDA newsgroup comp.lang.c++.leda

C. LEDA SOURCE CODE

```
/*******************************************************************************
*******
+
+  LEDA 3.5.1
+
+  _g_array.c
+
+  This file is part of the LEDA research version (LEDA-R) that can be
+  used free of charge in academic research and teaching. Any commercial
+  use of this software requires a license which is distributed by the
+  LEDA Software GmbH, Postfach 151101, 66041 Saarbruecken, FRG
+  (fax +49 681 31104).
+
+  Copyright (c) 1991-1997  by  Max-Planck-Institut fuer Informatik
+  Im Stadtwald, 66123 Saarbruecken, Germany
+  All rights reserved.
+
*******************************************************************************
*******/
#include <LEDA/graph.h>


//------------------------------------------------------------------------------
--------
// graph maps and arrays
//
// graph_map: base of node/edge/face_map/array
//
// by S. Naeher  (1995,1996)
//------------------------------------------------------------------------------
--------

graph_map::~graph_map()
{ if (g && g_index != 0) g->unregister_map(this);
  if (table) delete[] table;
 }


int graph_map::next_power(int s) const
{ if (s==0) return 0;
  int p = 1;
  while (p < s) p <<= 1;
  return p;
}


void  graph_map::re_init_entry(node v)
{ if (g_index > -1)
    init_entry(v->data[g_index]);
  else
   { int i = index(v);
     if (i < table_size)
     { clear_entry(table[i]);
       init_entry(table[i]);
      }
    }
 }
```

```
void  graph_map::re_init_entry(edge e)
{ if (g_index > -1)
    init_entry(e->data[g_index]);
  else
   { int i = index(e);
     if (i < table_size)
     { clear_entry(table[i]);
       init_entry(table[i]);
      }
    }
 }


void  graph_map::re_init_entry(face f)
{ if (g_index > -1)
    init_entry(f->data[g_index]);
  else
   { int i = index(f);
     if (i < table_size)
     { clear_entry(table[i]);
       init_entry(table[i]);
      }
    }
 }



void graph_map::init_table(GenPtr* start, GenPtr* stop)
{  if (g_index == -1)
     for(GenPtr* q=start; q < stop; q++) init_entry(*q);
   else
     if (g && g_index > 0)
     {
       switch (kind) {
       case 0 : { node v;
                  forall_nodes(v,*g) init_entry(v->data[g_index]);
                  break;
                 }
       case 1 : { edge e;
                  forall_edges(e,*g) init_entry(e->data[g_index]);
                  break;
                 }
       case 2 : { face f;
                  forall_faces(f,*g) init_entry(f->data[g_index]);
                  break;
                 }
       }
     }
}

void graph_map::clear_table()
{ if (g_index == -1)
    { GenPtr* stop = table + table_size;
      for(GenPtr* q=table; q < stop; q++) clear_entry(*q);
     }
  else
     if (g && g_index > 0)
     { switch (kind) {
```

```
        case 0 : { node v;
                   forall_nodes(v,*g) clear_entry(v->data[g_index]);
                   break;
                 }
        case 1 : { edge e;
                   forall_edges(e,*g) clear_entry(e->data[g_index]);
                   break;
                 }
        case 2 : { face f;
                   forall_faces(f,*g) clear_entry(f->data[g_index]);
                   break;
                 }
      }
    }

 }

void graph_map::resize_table(int sz)
{
  GenPtr* old_table = table;
  GenPtr* old_stop  = table + table_size;

  table_size = sz;
  table = new GenPtr[sz];
  if (table == 0) error_handler(1," graph_map: out of memory");

  GenPtr* p = old_table;
  GenPtr* q = table;
  while (p < old_stop) *q++ = *p++;

  init_table(q,table+sz);

  if (old_table != old_stop) delete[] old_table;
}


void graph_map::init(const graph* G, int sz, int k)
{
  if (g != G)
  { if (g && g_index != 0) g->unregister_map(this);
    kind = k;
    g = (graph*)G;
    if (g) g_index = g->register_map(this);
  }

  if (g_index > -1)
  { table = 0;
    table_size = 0;
    return;
   }

  clear_table();
  if (table_size > 0) delete[] table;

  table = 0;

  table_size = next_power(sz);
  if (table_size > 0)
  { table = new GenPtr[table_size];
    if (table == 0) error_handler(1," graph_map: out of memory");
   }
```

```
}


graph_map::graph_map(const graph* G, int k)
{ kind = k;
  g = (graph*)G;
  g_index = 0;
  table = 0;
  table_size = 0;
}


graph_map::graph_map(const graph* G, int sz, int k)
{
  kind = k;
  g = (graph*)G;
  g_index = -1;

  if (g) g_index =  g->register_map(this);

  if (g_index > -1)
  { table = 0;
    table_size = 0;
    return;
   }

  def_entry = 0;
  table = 0;
  table_size = next_power(sz);
  if (table_size > 0)
  { table = new GenPtr[table_size];
    if (table == 0) error_handler(1," graph_map: out of memory");
   }
}


graph_map::graph_map(const graph_map& M)
{ kind = M.kind;
  g = M.g;
  if (M.g_index == 0)
  { g_index = 0;
    table = 0;
    return;
   }
  g_index = -1;
  if (g) g_index = g->register_map(this);
  def_entry = 0;
  table = 0;
  table_size = M.table_size;
  if (table_size > 0)
  { table = new GenPtr[table_size];
    if (table == 0) error_handler(1," graph_map: out of memory");
    GenPtr* p = table;
    GenPtr* stop = M.table+M.table_size;
    for(GenPtr* q=M.table; q < stop; q++)
    { *p = *q;
      M.copy_entry(*p);
      p++;
     }
   }
}
```

```
graph_map& graph_map::operator=(const graph_map& M)
{ if (&M == this) return *this;
  clear_table();
  if (table_size > 0) delete[] table;
  if (g && g_index != 0) g->unregister_map(this);
  table = 0;
  kind = M.kind;
  g = M.g;
  if (M.g_index == 0)
  { g_index = 0;
    table = 0;
    return *this;
   }
  g_index = -1;
  if (g) g_index = g->register_map(this);
  table_size = M.table_size;
  if (table_size > 0)
  { table = new GenPtr[table_size];
    if (table == 0) error_handler(1," graph_map: out of memory");
    GenPtr* p = table;
    GenPtr* stop = M.table+M.table_size;
    for(GenPtr* q=M.table; q < stop; q++)
    { *p = *q;
      copy_entry(*p);
      p++;
     }
   }
  return *this;
}
```

```
/***************************************************************************
********
+
+  LEDA 3.5.1
+
+  _g_generate.c
+
+  This file is part of the LEDA research version (LEDA-R) that can be
+  used free of charge in academic research and teaching. Any commercial
+  use of this software requires a license which is distributed by the
+  LEDA Software GmbH, Postfach 151101, 66041 Saarbruecken, FRG
+  (fax +49 681 31104).
+
+  Copyright (c) 1991-1997  by  Max-Planck-Institut fuer Informatik
+  Im Stadtwald, 66123 Saarbruecken, Germany
+  All rights reserved.
+
****************************************************************************
*******/
#include <LEDA/graph.h>
#include <LEDA/ugraph.h>
#include <LEDA/vector.h>
#include <LEDA/matrix.h>
#include <LEDA/array2.h>

#include <ctype.h>
#include <math.h>

//---------------------------------------------------------------------------
--------
// some graph generators
//
// S. Naeher  (1995-1996)
//---------------------------------------------------------------------------
--------

void complete_graph(graph& G, int n, bool directed)
{
  G.clear();

  node* V = new node[n];

  for(int i=0;i<n;i++) V[i] = G.new_node();

  if (directed)
    { //memory_allocate_block(sizeof(node_struct),n);
      for(int i=0;i<n;i++)
        for(int j=0;j<n;j++) G.new_edge(V[i],V[j]);
     }
  else
    { //memory_allocate_block(sizeof(edge_struct),n*n/2);
      for(int i=0; i<n; i++)
        for(int j=i+1; j<n; j++) G.new_edge(V[i],V[j]);
     }

  delete[] V;
}


void grid_graph(graph& G, int n)
```

```
{ node_array<double> xcoord;
  node_array<double> ycoord;
  grid_graph(G,xcoord,ycoord,n);
 }

void grid_graph(graph& G, node_array<double>& xcoord,
                          node_array<double>& ycoord, int n)
{
  array2<node>  A(n,n);
  node v;
  int N = n*n;
  int x;
  int y;

  double d = 1.0/(n+1);

  G.clear();

  xcoord.init(G,N,0);
  ycoord.init(G,N,0);

  for(y=0; y<n; y++)
    for(x=0; x<n; x++)
      { A(x,y) = v = G.new_node();
        xcoord[v] = (x+1)*d;
        ycoord[v] = (y+1)*d;
       }

  for(x=0; x<n; x++)
    for(y=0; y<n; y++)
       { if (x < n-1) G.new_edge(A(x,y),A(x+1,y));
         if (y < n-1) G.new_edge(A(x,y),A(x,y+1));
        }
}


void complete_bigraph(graph& G, int n1, int n2, list<node>& A,
list<node>& B)
{
  G.clear();

  while (n1--)  A.append(G.new_node());
  while (n2--)  B.append(G.new_node());

  list_item a,b;
  forall_items(a,A)
    forall_items(b,B)
      G.new_edge(A[a],B[b]);
}

void user_graph(graph& G)
{ int  n = read_int("|V| = ");
  int  i,j;

  node* V = new node[n];
  for(j=0; j<n; j++) V[j] = G.new_node();

  for(j=0; j<n; j++)
  { list<int> il;
    int ok = false;
    while (!ok)
```

```
    { ok = true;
      cout << "edges from [" << j << "] to: ";
      il.read();
      forall(i,il)
        if (i < 0 || i >= n)
        { ok=false;
          cout << "illegal node " << i << "\n";
         }
     }
    forall(i,il) G.new_edge(V[j],V[i]);
  }
  G.print();
  if (Yes("save graph ? ")) G.write(read_string("file: "));

  delete[] V;
}


void test_graph(graph& G)
{
  G.clear();
  char c;

  do c = read_char("graph: f(ile) r(andom) c(omplete) p(lanar) u(ser):
");
  while (c!='f' && c!='r' && c!='c' && c!='p'&& c!='u');

  switch (c) {

   case 'f' : { G.read(read_string("file: "));
                break;
               }

   case 'u' : { user_graph(G);
                break;
               }

   case 'c' : { complete_graph(G,read_int("|V| = "));
                break;
               }

   case 'r' : { int n = read_int("|V| = ");
                int m = read_int("|E| = ");
                random_graph(G,n,m);
                break;
               }

   case 'p' : { random_planar_graph(G,read_int("|V| = "));
                break;
               }
   }//switch

}

void test_ugraph(ugraph& G)
{
  G.clear();
  char c;
```

```
  do c = read_char("graph: f(ile) r(andom) c(omplete) p(lanar) u(ser):
");
  while (c!='f' && c!='r' && c!='c' && c!='p'&& c!='u');

  int  i;
  node v;

  switch (c) {

  case 'f' : { G.read(read_string("file: "));
              break;
             }

   case 'u' : { int  n = read_int("|V| = ");
                int  j = 0;
                node* V = new node[n];
                for(i=0; i<n; i++) V[i] = G.new_node();
                forall_nodes(v,G)
                  { list<int> il;
                    cout << "edges from " << j++ << " to: ";
                    il.read();
                    forall(i,il)
                      if (i >= 0 && i < n) G.new_edge(v,V[i]);
                      else cerr << "illegal node " << i << "
(ignored)\n";
                  }
                G.print();
                if (Yes("save graph ? ")) G.write(read_string("file:
"));
                delete[] V;
                break;
               }

   case 'c' : { int n = read_int("|V| = ");
                complete_graph(G,n);
                break;
               }

   case 'r' : { int n = read_int("|V| = ");
                int m = read_int("|E| = ");
                random_graph(G,n,m);
                break;
               }

   }//switch

}



void test_bigraph(graph& G, list<node>& A, list<node>& B)
{
  int a,b;
  int n1 = 0;
  int n2 = 0;
  char c;

  do c = read_char("bipartite graph: f(ile) r(andom) c(omplete) u(ser):
");
```

```
  while (c!='f' && c!='r' && c!='c' && c!='u');

  A.clear();
  B.clear();
  G.clear();

  if (c!='f')
   { n1 = read_int("|A| = ");
     n2 = read_int("|B| = ");
    }


  switch (c) {

  case 'f' : { G.read(read_string("file: "));
               node v;
               forall_nodes(v,G)
               if (G.outdeg(v) > 0) A.append(v);
               else B.append(v);

               break;
              }

   case 'u' : { node* AV = new node[n1+1];
                node* BV = new node[n2+1];

                for(a=1; a<=n1; a++)  A.append(AV[a] = G.new_node());
                for(b=1; b<=n2; b++)  B.append(BV[b] = G.new_node());

                for(a=1; a<=n1; a++)
                { list<int> il;
                  cout << "edges from " << a << " to: ";
                  il.read();
                  forall(b,il)
                    if (b<=n2) G.new_edge(AV[a],BV[b]);
                    else break;
                  if (b>n2) break;
                 }
                delete[] AV;
                delete[] BV;
                break;
               }

   case 'c' : complete_bigraph(G,n1,n2,A,B);
              break;

   case 'r' : { int m = read_int("|E| = ");
                random_bigraph(G,n1,n2,m,A,B);
                break;
               }

        } // switch

}


void cmdline_graph(graph& G, int argc, char** argv)
{
  // construct graph from cmdline arguments
```

```
  if (argc == 1)              // no arguments
     { test_graph(G);
       return;
      }
  else
     if (argc == 2)          // one argument
        { if (isdigit(argv[1][0]))
             { cout << "complete graph |V| = " << argv[1];
               newline;
               newline;
               complete_graph(G,atoi(argv[1]));
              }
          else
             { cout << "reading graph from file " << argv[1];
               newline;
               newline;
               G.read(argv[1]);
              }
          return;
         }
     else
        if (argc == 3 && isdigit(argv[1][0]) && isdigit(argv[1][0]))
           { cout << "random graph |V| = " << argv[1] << "   |E| = " <<
argv[2];
             newline;
             newline;
             random_graph(G,atoi(argv[1]),atoi(argv[2]));
             return;
            }

  error_handler(1,"cmdline_graph: illegal arguments");
}



//------------------------------------------------------------------------
--------
// triangulated planar graph
//------------------------------------------------------------------------
--------


struct triang_point {

double x;
double y;
node   v;

LEDA_MEMORY(triang_point)

triang_point(double a=0, double b = 0) { x = a; y = b; v = nil; }
triang_point(const triang_point& p)    { x = p.x; y = p.y; v = p.v; }
~triang_point() {};

friend bool right_turn(const triang_point& a, const triang_point& b,
const triang_point& c)
{ return (a.y-b.y)*(a.x-c.x)+(b.x-a.x)*(a.y-c.y) > 0; }

friend bool left_turn(const triang_point& a, const triang_point& b,
const triang_point& c)
```

```
{ return (a.y-b.y)*(a.x-c.x)+(b.x-a.x)*(a.y-c.y) < 0; }


friend bool operator==(const triang_point& a, const triang_point& b)
{ return a.x == b.x && a.y == b.y; }

friend ostream& operator<<(ostream& out, const triang_point& p)
{ return out << p.x << " " << p.y; }

friend istream& operator>>(istream& in, triang_point& p)
{ return in >> p.x >> p.y; }

friend int compare(const triang_point& p, const triang_point& q)
{ int c = compare(p.x,q.x);
  if (c==0) c = compare(p.y,q.y);
  return c;
 }

};



void triangulated_planar_graph(graph& G, list<node>& outer_face,
                                          node_array<double>& xcoord,
                                          node_array<double>& ycoord, int
n)
{
  G.clear();

  list<triang_point> L;

  while(n--)
  { double x = rand_int(0,1000000)/1000000.0;
    double y = rand_int(0,1000000)/1000000.0;
    L.append(triang_point(x,y));
   }

  L.sort();  // sort triang_points lexicographically

  list<triang_point> CH;
  list_item last;
  triang_point p,q;


  // eliminate multiple triang_points

  list_item it;
  forall_items(it,L)
  { list_item it1 = L.succ(it);
    while (it1 != nil && L[it1] == L[it])
    { L.del(it1);
      it1 = L.succ(it);
     }
   }

  n = L.length();

  xcoord.init(G,n,0);
  ycoord.init(G,n,0);

  forall_items(it,L)
```

```
{ node v = G.new_node();
  xcoord[v] = L[it].x;
  ycoord[v] = L[it].y;
  L[it].v = v;
 }

// initialize convex hull with first two points

p = L.pop();
CH.append(p);

while (L.head() == p) L.pop();

q = L.pop();
last = CH.append(q);

G.new_edge(p.v,q.v);


// scan remaining points

forall(p,L)
{


  node v = p.v;

  G.new_edge(v,CH[last].v);

  // compute upper tangent (p,up)

  list_item up = last;
  list_item it = CH.cyclic_succ(up);

  while (left_turn(CH[it],CH[up],p))
  { up = it;
    it = CH.cyclic_succ(up);
    G.new_edge(v,CH[up].v);
   }


  // compute lower tangent (p,low)

  list_item low = last;
  it = CH.cyclic_pred(low);

  while (right_turn(CH[it],CH[low],p))
  { low = it;
    it = CH.cyclic_pred(low);
    G.new_edge(v,CH[low].v);
   }


  // remove all points between up and low

  if (up != low)
  { it = CH.cyclic_succ(low);

    while (it != up)
    { CH.del(it);
      it = CH.cyclic_succ(low);
```

```
        }
      }

     // insert new point

     last = CH.insert(p,low);

    }

  outer_face.clear();
  forall(p,CH) outer_face.append(p.v);

}


void triangulated_planar_graph(graph& G, int m)
{ node_array<double> xcoord;
  node_array<double> ycoord;
  list<node> L;
  triangulated_planar_graph(G,L,xcoord,ycoord,m);
 }


static bool tutte_embed(const graph& G, const node_array<bool>& fixed,
                        node_array<double>& xpos, node_array<double>&
ypos)
{ node v,w;
  edge e;

  list<node> other_nodes;
  forall_nodes(v,G)
      if(!fixed[v]) other_nodes.append(v);

  node_array<int> ind(G);          // position of v in other_nodes and A

  int i = 0;
  forall(v,other_nodes) ind[v] = i++;

  int n = other_nodes.size();   // #other nodes
  vector coord(n);              // coordinates (first x then y)
  vector rhs(n);                // right hand side
  matrix A(n,n);                // equations

  // initialize non-zero entries in matrix A
  forall(v,other_nodes)
  {
    double one_over_d = 1.0/double(G.degree(v));
    forall_inout_edges(e,v)
    {
      // get second node of e
      w = (v == source(e)) ? target(e) : source(e);
      if(!fixed[w]) A(ind[v],ind[w]) = one_over_d;
    }
    A(ind[v],ind[v]) = -1;
  }

  if(!A.det()) return false;

  // compute right hand side for x coordinates
  forall(v,other_nodes)
  { rhs[ind[v]] = 0;
```

```
    double one_over_d = 1.0/double(G.degree(v));
    forall_inout_edges(e,v)
    { // get second node of e
      w = (v == source(e)) ? target(e) : source(e);
      if(fixed[w]) rhs[ind[v]] -= (one_over_d*xpos[w]);
    }
  }

  // compute x coordinates
  coord = A.solve(rhs);
  forall(v,other_nodes) xpos[v] = coord[ind[v]];

  // compute right hand side for y coordinates
  forall(v,other_nodes)
  { rhs[ind[v]] = 0;
    double one_over_d = 1.0/double(G.degree(v));
    forall_inout_edges(e,v)
    { // get second node of e
      w = (v == source(e)) ? target(e) : source(e);
      if(fixed[w]) rhs[ind[v]] -= (one_over_d*ypos[w]);
    }
  }

  // compute y coordinates
  coord = A.solve(rhs);
  forall(v,other_nodes) ypos[v] = coord[ind[v]];

  return true;
}


void triangulated_planar_graph(graph& G, node_array<double>& xcoord,
                                         node_array<double>& ycoord, int
n)
{ list<node> L;
  triangulated_planar_graph(G,L,xcoord,ycoord,n);

  if (n > 128) return;

  node_array<bool> fixed(G,false);

  double step  = 6.2832/L.length();
  double alpha = 0;
  node v;
  forall(v,L)
  { xcoord[v] = cos(alpha);
    ycoord[v] = sin(alpha);
    alpha+=step;
    fixed[v] = true;
  }

  tutte_embed(G,fixed,xcoord,ycoord);
 }
```

```
/***************************************************************************
********
+
+  LEDA 3.5.1
+
+  _g_gmlio.c
+
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+
****************************************************************************
*******/
// -------------------------------------------------------------------- //
// writing LEDA graphs in GML format                                     //
// reading LEDA graphs in GML format                                     //
//                                                                       //
// David Alberts (1996)                                                  //
// David Alberts (1997) new version, accepts unknown lists, etc.         //
//                      no more lex/yacc                                 //
// -------------------------------------------------------------------- //

#include<LEDA/graph.h>
#include<LEDA/stream.h>
#include<LEDA/gml_graph.h>

bool graph::write_gml(string outfile,
                      void (*node_cb)(ostream&,const graph*, const
node),
                      void (*edge_cb)(ostream&,const graph*, const
edge)) const
// writes a graph description in GML format to outfile.
// If an error occurs, false is returned.
{
  file_ostream out(outfile);

  if(out.fail()) return false;
  else           return write_gml(out,node_cb,edge_cb);
}

bool graph::write_gml(ostream& out,
                      void (*node_cb)(ostream&,const graph*, const
node),
                      void (*edge_cb)(ostream&,const graph*, const
edge)) const
// writes a graph description in GML format to outfile.
// If an error occurs, false is returned.
{
  if(out.fail()) return false;

  string void_str("void");

  out << "Creator " << '"' << "LEDA write_gml" << '"' << "\n\n";
  out << "graph [\n\n";
  out << "  directed " << (is_directed() ? 1 : 0) << "\n";
```

```
  out << "\n";

  node v;
  if((string(node_type()) != void_str) || node_cb)
  {
    forall_nodes(v,*this)
    {
      out << "  node [\n";
      out << "    id " << index(v) << "\n";
      if(string(node_type()) != void_str)
      {
        out << "    parameter " << '"' << get_node_entry_string(v);
        out << '"' << "\n";
      }
      if(node_cb) (*node_cb)(out,this,v);
      out << "  ]\n";
    }
  }
  else
    forall_nodes(v,*this) out << "  node [ id " << index(v) << " ]\n";

  out << "\n";

  edge e;
  if((string(edge_type()) != void_str) || edge_cb)
  {
    forall_edges(e,*this)
    {
      out << "  edge [\n";
      out << "    source " << index(source(e)) << "\n";
      out << "    target " << index(target(e)) << "\n";
      if(string(edge_type()) != void_str)
      {
        out << "    parameter " << '"' << get_edge_entry_string(e);
        out << '"' << "\n";
      }
      if(edge_cb) (*edge_cb)(out,this,e);
      out << "  ]\n";
    }
  }
  else
  {
    forall_edges(e,*this)
    {
      out << "  edge [ source " << index(source(e)) << " ";
      out << "target " << index(target(e)) << " ]\n";
    }
  }
  out << "\n]\n";

  return true;
}


bool graph::read_gml(string s)
{
  gml_graph* parser = new gml_graph(*this,s.cstring());
  bool ok = !parser->errors();
  delete parser;
  return ok;
}
```

```
bool graph::read_gml(istream& in)
{
  gml_graph* parser = new gml_graph(*this,in);
  bool ok = !parser->errors();
  delete parser;
  return ok;
}
```

```
/***********************************************************************
********
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+  LEDA 3.5.1
+
+  _g_inout.c
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+
************************************************************************
*******/

//----------------------------------------------------------------------
--------
// graph i/o
//
// S. Naeher  (last modified: December 1996)
//----------------------------------------------------------------------
--------


#include <LEDA/graph.h>
#include <LEDA/stream.h>
#include <ctype.h>
#include <string.h>

const char delim = '|';

void graph::write(string file_name) const
{ ofstream out(file_name);
  if (out.fail())
    error_handler(1,string("graph::write() cannot open file
%s",file_name));
  write(out);
}


void graph::write(ostream& out) const
{
  int* A = new int[max_n_index+1];
  int* B = new int[max_e_index+1];

  for(int i=0; i<= max_e_index; i++) B[i] = 0;

  // nodes get numbers from 1 to |V|

  int n_count = 1;
  int e_count = 1;

  out << "LEDA.GRAPH" << endl;
  out << node_type()  << endl;
  out << edge_type()  << endl;
```

```
  out << v_list.length() << endl;

  node v;
  forall_nodes(v,*this)
  { out << delim << '{';
    write_node_entry(out,v->data[0]);
    out << '}' << delim << endl;
    A[index(v)] = n_count++;
   }

  out << number_of_edges() << endl;

  forall_nodes(v,*this)
  { edge e;
    int s = A[index(v)];
    forall_adj_edges(e,v)
    { if (source(e) != v) continue; // necessary for ugraphs
      int t = A[index(target(e))];
      int r = (e->rev) ? B[index(e->rev)] : 0;
      out << s << " " << t << " " << r << " " << delim << '{';
      write_edge_entry(out,e->data[0]);
      out << '}' << delim << endl;
      B[index(e)] = e_count++;
     }
   }

 delete[] A;
 delete[] B;

}

int graph::read(string file_name)
{ ifstream in(file_name);
  if (in.fail())  return 1;
  return read(in);
}


static void read_data_entry(istream& in, char* buf, int buf_sz)
{ char* p = buf-1;
  char  c;

  do in.get(c); while (isspace(c));
  if (c != delim)
  { in.putback(c);
    string line = read_line(in);
    strcpy(buf,line.cstring());
    return;
   }

  in.get(c);
  if (c != '{')
    error_handler(1,"graph::read(): error in graph format.");

  int nested = 1;

  while (nested)
  { in.get(c);
    if (c == delim && p >= buf)
    { if (*p == '}')
         nested--;
```

```
        else
         { if (buf_sz-- <= 0)
               error_handler(1,"graph::read: data overflow");
           *++p = c;
           in.get(c);
           if (c == '{') nested++;
          }
      }

     if (nested)
     { if (buf_sz-- <= 0)
          error_handler(1,"graph::read: data overflow");
       *++p = c;
      }
   }

  *p = '\0';
}


int graph::read(istream& in)
{

  clear();

  int result = 0;
  int n,i,v,w,r;

  string this_n_type = node_type();
  string this_e_type = edge_type();

  string d_type,n_type,e_type;

  in >> d_type;
  in >> n_type;
  in >> e_type;
  in >> n;

  if (d_type != "LEDA.GRAPH") return 3;

  read_line(in);

  node* A = new node[n+1];

  char data_str[1024];

  if (this_n_type == "void" || n_type != this_n_type)  // do not read
node info
    { for (i=1; i<=n; i++)
      { A[i] = new_node();
        read_data_entry(in,data_str,1024);
       }
      if (n_type != this_n_type) result = 2;   // incompatible node
types
     }
  else
    if (this_n_type == "string")
      for (i=1; i<=n; i++)
      { A[i] = new_node(0);
        read_data_entry(in,data_str,1024);
        A[i]->data[0] = leda_copy(string(data_str));
```

```
      }
    else
      for (i=1; i<=n; i++)
      { A[i] = new_node(0);
        read_data_entry(in,data_str,1024);
        istrstream str_in(data_str,strlen(data_str));
        read_node_entry(str_in,A[i]->data[0]);
      }

  in >> n;        // number of edges
  edge* B = new edge[n+1];

  if (this_e_type == "void" || e_type != this_e_type) // do not read
edge info
    { if (e_type != this_e_type) result = 2;   // incompatible edge
types
      for (i=1; i<=n; i++)
      { in >> v >> w >> r;
        edge e = new_edge(A[v],A[w]);
        read_data_entry(in,data_str,1024);
        B[i] = e;
        if (r > 0) set_reversal(e,B[r]);
      }
     }
  else
    if (this_e_type == "string")
      for (i=1; i<=n; i++)
      { in >> v >> w >> r;
        edge e = new_edge(A[v],A[w],GenPtr(0));
        read_data_entry(in,data_str,1024);
        e->data[0] = leda_copy(string(data_str));
        B[i] = e;
        if (r > 0) set_reversal(e,B[r]);
       }
    else
      for (i=1; i<=n; i++)
      { in >> v >> w >> r;
        edge e = new_edge(A[v],A[w],GenPtr(0));
        read_data_entry(in,data_str,1024);
        istrstream str_in(data_str,strlen(data_str));
        read_edge_entry(str_in,e->data[0]);
        B[i] = e;
        if (r > 0) set_reversal(e,B[r]);
       }

  delete[] A;
  delete[] B;

  return result;
}


void graph::print_node(node v,ostream& o) const
{ if (super() != 0)
     super()->print_node(node(graph::inf(v)),o);
  else
     { o << "[" << index(v) <<"]" ;
       print_node_entry(o,v->data[0]);
      }
}
```

```
void graph::print_edge(edge e,ostream& o) const
{ if (super() != 0)
      super()->print_edge(edge(graph::inf(e)),o);
  else
     { o <<   "[" << index(source(e)) << "]";
       o <<  ((undirected) ? "==" : "--");
       print_edge_entry(o,e->data[0]);
       o <<  ((undirected) ? "==" : "-->");
       o << "[" << index(target(e)) << "]";
      }
}


void graph::print(string s, ostream& out) const
{ node v;
  edge e;
  out << s << endl;
  forall_nodes(v,*this)
  { print_node(v,out);
    out << " : ";
    forall_adj_edges(e,v) print_edge(e,out);
    out << endl;
   }
  out << endl;
}



// convert node and edge entries into a string and vice versa

string graph::get_node_entry_string(node v) const
{ ostrstream out;
  write_node_entry(out,v->data[0]);
  out << ends;
  char* p = out.str();
  string s(p);
  delete[] p;
  return s;
 }

string graph::get_edge_entry_string(edge e) const
{ ostrstream out;
  write_edge_entry(out,e->data[0]);
  out << ends;
  char* p = out.str();
  string s(p);
  delete[] p;
  return s;
 }


void graph::set_node_entry(node v, string s)
{ clear_node_entry(v->data[0]);
  if (strcmp(node_type(),"string") == 0)
     v->data[0] = leda_copy(s);
  else
    { istrstream in(s.cstring());
      read_node_entry(in,v->data[0]);
     }
 }
```

```
void graph::set_edge_entry(edge e, string s)
{ clear_edge_entry(e->data[0]);
  if (strcmp(edge_type(),"string") == 0)
      e->data[0] = leda_copy(s);
  else
    { istrstream in(s.cstring());
      read_edge_entry(in,e->data[0]);
     }
 }
```

```
/***********************************************************************
*******
+
+  LEDA 3.5.1
+
+  _g_map.c
+
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+
************************************************************************
*******/
#include <LEDA/graph.h>

// reversal edges

edge graph::face_cycle_succ(edge e) const
{ return cyclic_adj_pred(reversal(e)); }

edge graph::face_cycle_pred(edge e) const
{ return reversal(cyclic_adj_succ(e)); }

edge graph::succ_face_edge(edge e) const
{ return cyclic_adj_pred(reversal(e)); }

edge graph::pred_face_edge(edge e) const
{ return reversal(cyclic_adj_succ(e)); }


void graph::set_reversal(edge e, edge r)
{ if ( source(e) != target(r) || target(e) != source(r) )
  error_handler(1,"graph::set_reversal: edges are not reversals of each
other");
  e->rev = r;
  r->rev = e;
}


static int map_edge_ord1(const edge& e) { return index(source(e)); }
static int map_edge_ord2(const edge& e) { return index(target(e)); }

bool graph::make_map()
{
 // computes for every edge e = (v,w) in G its reversal r = (w,v)
 // in G ( nil if not present). Returns true if every edge has a
 // reversal and false otherwise.

  int n     = max_node_index();
  int count = 0;

  list<edge> El1 = all_edges();
  list<edge> El2 = El1;

  edge e;
```

```
  forall(e,El1) e->rev = 0;

  El1.bucket_sort(0,n,&map_edge_ord2);
  El1.bucket_sort(0,n,&map_edge_ord1);
  El2.bucket_sort(0,n,&map_edge_ord1);
  El2.bucket_sort(0,n,&map_edge_ord2);


  // merge El1 and El2 to find corresponding edges

  while (! El1.empty() && ! El2.empty())
  { edge e = El1.head();
    edge r = El2.head();
    if (target(r) == source(e))
      if (source(r) == target(e))
         { e->rev = r;
           El2.pop();
           El1.pop();
           count++;
          }
      else
         if (index(source(r)) < index(target(e)))
             El2.pop();
         else
             El1.pop();

    else
      if (index(target(r)) < index(source(e)))
          El2.pop();
      else
          El1.pop();

   }

  return (count == number_of_edges()) ? true : false;
}


void graph::make_map(list<edge>& R)
{ if (make_map()) return;
  list<edge> el = all_edges();
  edge e;
  forall(e,el)
  { if (e->rev == nil)
    { edge r = new_edge(target(e),source(e));
      e->rev = r;
      r->rev = e;
      R.append(r);
     }
   }
}



extern bool PLANAR(graph&, bool=false);

void graph::make_planar_map()
{ if (!graph::make_map())
```

```
      error_handler(1,"graph::make_planar_map: graph is not
bidirected");
  if (!PLANAR(*this,true))
      error_handler(1,"graph::make_planar_map: Graph is not planar.");
  compute_faces();
}


face  graph::new_face(GenPtr i)
{ copy_face_entry(i);
  return add_face(i);
 }

face  graph::new_face()
{ GenPtr i = 0;
  init_face_entry(i);
  return add_face(i);
 }


list<edge> graph::adj_edges(face f) const
{ list<edge> result(f->head);
  edge e1 = face_cycle_succ(f->head);
  while (e1!=f->head)
  { result.append(e1);
    e1 = face_cycle_succ(e1);
   }
  return result;
 }

list<node> graph::adj_nodes(face f) const
{ list<node> result(source(f->head));
  edge e1 = face_cycle_succ(f->head);
  while (e1!=f->head)
  { result.append(source(e1));
    e1 = face_cycle_succ(e1);
   }
  return result;
 }

list<face> graph::adj_faces(node v) const
{ list<face> result;
  edge e;
  forall_out_edges(e,v) result.append(adj_face(e));
  return result;
 }


void graph::print_face(face f) const
{ cout << string("F[%2d]",index(f));
  cout << "(";
  print_face_entry(cout,f->data[0]);
  cout << "): ";
  edge e;
  forall_face_edges(e,f)
   cout << string("[%2d]",index(target(e)));
 }
```

```
void graph::compute_faces()
{
  del_all_faces();

  FaceOf = new graph_map(this,1,0);

  edge e;
  forall_edges(e,*this)
  { if (e->rev == nil)
       error_handler(1,"graph::compute_faces: no map (reversal edge
missing)");
     access_face(e) = nil;
    }


  forall_edges(e,*this)
  { if (access_face(e) != nil) continue;
    face f = new_face();
    f->head = e;
    edge e1 = e;
    int count = 0;
    do { access_face(e1) = f;
         e1 = face_cycle_succ(e1);
         count++;
       } while (e1 != e);
    f->sz = count;
   }
}



edge graph::split_map_edge(edge e)
{
  /* splits edge e and its reversal by inserting a new node u (node_inf)
               e                                e            rr
        ----------->                       --------->   --------->
     (v)              (w)    ====>   (v)              (u)            (w)
        <-----------                       <---------   <---------
               r                                er           r
     returns edge rr
  */

  edge r = e->rev;

  if (r == nil)
    error_handler(1,"graph::split_map_edge(e): reversal of edge e
missing.");

  node v = source(e);
  node w = target(e);
  node u = new_node();

  // remove e and r from corresponding in-lists
  w->del_adj_edge(e,1,1);
  v->del_adj_edge(r,1,1);

  // insert e and r in in-list of u
  e->term[1] = u;
  r->term[1] = u;
```

```
  u->append_adj_edge(e,1,1);
  u->append_adj_edge(r,1,1);

  // create reverse edges rr and re
  edge rr = graph::new_edge(u,w);
  edge er = graph::new_edge(u,v);

  set_reversal(e,er);
  set_reversal(r,rr);

  access_face(rr) = access_face(e);
  access_face(er) = access_face(r);

  return rr;
}


edge graph::new_map_edge(edge e1, edge e2)
{ edge e = graph::new_edge(e1,source(e2));
  edge r = graph::new_edge(e2,source(e1));
  set_reversal(e,r);
  return e;
}


edge graph::split_face(edge e1, edge e2)
{
  face f1 = access_face(e1);
  face f2 = access_face(e2);

  if (f1 != f2)
    error_handler(1,"planar_map::new_edge: new edge must lie in a
face.");

  f2 = new_face();

  edge x = graph::new_edge(e1,source(e2));
  edge y = graph::new_edge(e2,source(e1));
  set_reversal(x,y);

  f1->head = x;
  f2->head = y;

  access_face(x) = f1;

  do { access_face(y) = f2;
       y = face_cycle_succ(y);
     } while (y != f2->head);

  return x;
}


list<edge> graph::triangulate_map()
{
/* G is a planar map. This procedure triangulates all faces of G
   without introducing multiple edges. The algorithm was suggested by
   Christian Uhrig and Torben Hagerup.

   Description:
```

```
   Triangulating a planar graph G, i.e., adding edges
   to G to obtain a chordal planar graph, in linear time:

   1) Compute a (combinatorial) embedding of G.

   2) Step through the vertices of G. For each vertex u,
   triangulate those faces incident on u that have not
   already been triangulated. For each vertex u, this
   consists of the following:

     a) Mark the neighbours of u. During the processing
   of u, a vertex will be marked exactly if it is a
   neighbour of u.

     b) Process in any order those faces incident on u
   that have not already been triangulated. For each such
   face with boundary vertices u=x_1,...,x_n,
        I)    If n=3, do nothing; otherwise
        II)   If x_3 is not marked, add an edge {x_1,x_3},
              mark x_3 and continue triangulating the face
              with boundary vertices x_1,x_3,x_4,...,x_n.
        III)  If x_3 is marked, add an edge {x_2,x_4} and
              continue triangulating the face with boundary
              vertices x_1,x_2,x_4,x_5,...,x_n:

     c) Unmark the neighbours of x_1.

   Proof of correctness:

   A) All faces are triangulated.
   This is rather obvious.

   B) There will be no multiple edges.
   During the processing of a vertex u, the marks on
   neighbours of u clearly prevent us from adding a multiple
   edge with endpoint u. After the processing of u, such an
   edge is not added because all faces incident on u have
   been triangulated. This takes care of edges added in
   step II).
   Whenever an edge {x_2,x_4} is added in step III), the
   presence of an edge {x_1,x_3} implies, by a topological
   argument, that x_2 and x_4 are incident on exactly one
   common face, namely the face currently being processed.
   Hence we never add another edge {x_2,x_4}.
*/

  node v;
  edge x;
  list<edge> L;

  node_array<int>  marked(*this,0);

  if ( !make_map() )
  error_handler(1,"TRIANGULATE_PLANAR_MAP: graph is not a map.");

  forall_nodes(v,*this)
  {
    list<edge> El = adj_edges(v);
    edge e,e1,e2,e3;
```

```
    forall(e1,El) marked[target(e1)]=1;

    forall(e,El)
    {
      e1 = e;
      e2 = face_cycle_succ(e1);
      e3 = face_cycle_succ(e2);

      while (target(e3) != v)
      // e1,e2 and e3 are the first three edges in a clockwise
      // traversal of a face incident to v and t(e3) is not equal
      // to v.
       if ( !marked[target(e2)] )
        { // we mark w and add the edge {v,w} inside F, i.e., after
          // dart e1 at v and after dart e3 at w.

          marked[target(e2)] = 1;
          L.append(x  = new_edge(e3,source(e1)));
          L.append(e1 = new_edge(e1,source(e3)));
          set_reversal(x,e1);
          e2 = e3;
          e3 = face_cycle_succ(e2);
        }
        else
        { // we add the edge {source(e2),target(e3)} inside F, i.e.,
          // after dart e2 at source(e2) and before dart
          // reversal_of[e3] at target(e3).

          e3 = face_cycle_succ(e3);
          L.append(x  = new_edge(e3,source(e2)));
          L.append(e2 = new_edge(e2,source(e3)));
          set_reversal(x,e2);
        }
     //end of while

    } //end of stepping through incident faces

   node w;
   forall_adj_nodes(w,v) marked[w] = 0;

  } // end of stepping through nodes

 return L;

}


face graph::join_faces(edge x)
{
  edge y  = reversal(x);

  if (y == nil)
      error_handler(1,"join_faces: graph must be a map.");

  if (access_face(x) == nil || access_face(y) == nil)
      error_handler(1,"join_faces: no face associated with edges.");

  edge e  = face_cycle_succ(y);
  face F1 = adj_face(x);
  face F2 = adj_face(y);
```

```
  if (F1 != F2)
  { edge e = face_cycle_succ(y);
    F1->head = e;
    while ( e != y )
    { access_face(e) = F1;
      e = face_cycle_succ(e);
     }
    clear_face_entry(F2->data[0]);
    del_face(F2);
   }
  else
  { e = face_cycle_succ(e);
    if (e != y) // no isolated edge
      F1->head = e;
    else
      { clear_face_entry(F1->data[0]);
        del_face(F1);
        F1 = F2;
       }
   }

  graph::del_edge(x);
  graph::del_edge(y);

  return F1;
}



void graph::make_bidirected(list<edge>& L)
{ Make_Bidirected(*this,L); }

bool graph::is_bidirected() const
{ edge_array<edge> rev(*this,0);
  return Is_Bidirected(*this,rev);
}

bool graph::is_map() const
{ return Is_Map(*this); }
```

```
/**********************************************************************
********
+
+  LEDA 3.5.1
+
+  _g_misc.c
+
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+
***********************************************************************
*******/
#include <LEDA/graph.h>
#include <LEDA/ugraph.h>
#include <LEDA/graph_alg.h>

//--------------------------------------------------------------------
--------
// S. Naeher
//          last modified ( April 1997)
//--------------------------------------------------------------------
--------

node_array<int>* num_ptr;

static int source_num(const edge& e) { return (*num_ptr)[source(e)]; }
static int target_num(const edge& e) { return (*num_ptr)[target(e)]; }


bool Is_Simple(const graph& G)
{
  // return true iff G is simple, i.e, has no parallel edges

  list<edge> el= G.all_edges();

  if (el.empty()) return true;


  int n = 0;

  node_array<int> num(G);

  node v;
  forall_nodes(v,G) num[v]= n++;

  num_ptr= &num;
  el.bucket_sort(0,n-1,&source_num);
  el.bucket_sort(0,n-1,&target_num);

  edge e0 = el.pop();
  edge e;
  forall(e,el)
  { if (source(e0) == source(e) && target(e0) == target(e) )
       return false;
```

```
    else
        e0 = e;
   }

  return true;

}


list<node> Delete_Loops(graph& G)
{ list<edge> loops;
  list<node> L;
  edge e;
  forall_edges(e,G)
  { node v = source(e);
    node w = target(e);
    if (v == w)
    { L.append(v);
      loops.append(e);
     }
   }
  forall(e,loops) G.del_edge(e);
  return L;
 }


list<edge> Make_Simple(graph& G)
{
  list<edge> L;

  //use bucket sort to find and eliminate parallel edges

  list<edge> el = G.all_edges();

  if (el.empty()) return L;


  node_array<int> num(G);
  int  n = 0;
  node v;
  forall_nodes(v,G) num[v] = n++;

  num_ptr = &num;

  el.bucket_sort(0,n-1,&source_num);
  el.bucket_sort(0,n-1,&target_num);

  bool deleted = false;
  edge e0 = el.pop();

  edge e;
  forall(e,el)
    if (source(e0) == source(e) && target(e0) == target(e))
     { G.del_edge(e);
       if (!deleted) L.append(e0);
       deleted = true;
      }
    else
     { deleted = false;
       e0 = e;
      }
```

```
  return L;

 }


static int edge_ord1(const edge& e) { return index(source(e)); }
static int edge_ord2(const edge& e) { return index(target(e)); }

bool Is_Bidirected(const graph& G, edge_array<edge>& reversal)
{
 // computes for every edge e = (v,w) in G its reversal reversal[e] =
(w,v)
 // in G ( nil if not present). Returns true if every edge has a
 // reversal and false otherwise.

  int n = G.max_node_index();
  int count = 0;

  edge e,r;

  forall_edges(e,G) reversal[e] = 0;

  list<edge> El = G.all_edges();
  El.bucket_sort(0,n,&edge_ord2);
  El.bucket_sort(0,n,&edge_ord1);

  list<edge> El1 = G.all_edges();
  El1.bucket_sort(0,n,&edge_ord1);
  El1.bucket_sort(0,n,&edge_ord2);


  // merge El and El1 to find corresponding edges

  while (! El.empty() && ! El1.empty())
  { e = El.head();
    r = El1.head();

    if (target(r) == source(e))
      if (source(r) == target(e))
         { reversal[e] = r;
           El1.pop();
           El.pop();
           count++;
          }
      else
         if (index(source(r)) < index(target(e)))
             El1.pop();
         else
             El.pop();

    else
      if (index(target(r)) < index(source(e)))
          El1.pop();
      else
          El.pop();

    }

   return (count == G.number_of_edges()) ? true : false;
```

```
}


void Make_Bidirected(graph& G, list<edge>& R)
{
  // make graph bi-directed by inserting reversal edges
  // appends new edges to R

  edge_array<edge> rev(G,nil);

  if (Is_Bidirected(G,rev)) return;

  // build list L of edges having no reversals

  list<edge> L;
  edge e;
  forall_edges(e,G)
   if (rev[e] == nil) L.append(e);

  // insert missing reversals
  forall(e,L)
  { edge r = G.new_edge(target(e),source(e));
    R.append(r);
   }
}


list<edge> Make_Bidirected(graph& G)
{ list<edge> R;
  Make_Bidirected(G,R);
  return R;
 }

static void dfs(node v, int& count1, int& count2, node_array<int>&
dfsnum,
                                                                node_array<int>&
compnum)
{ dfsnum[v] = ++count1;
  edge e;
  forall_adj_edges(e,v)
  { node w = target(e);
    if (dfsnum[w] == 0)
      dfs(w,count1,count2,dfsnum,compnum);
   }
  compnum[v] = ++count2;
}


bool Is_Acyclic(const graph& G, list<edge>& back)
{
  //compute dfs and completeion numbers
  node_array<int> dfsnum(G,0);
  node_array<int> compnum(G,0);
  int count1 = 0;
  int count2 = 0;
  node v;
  forall_nodes(v,G)
    if (dfsnum[v] == 0)
        dfs(v,count1,count2,dfsnum,compnum);
```

```
  // compute back edges
  back.clear();
  edge e;
  forall_edges(e,G)
  { node v = source(e);
    node w = target(e);
    if (v == w || (dfsnum[v] > dfsnum[w] && compnum[v] < compnum[w]))
      back.append(e);
   }

  return back.empty();
}


bool Is_Acyclic(const graph& G)
{ list<edge> dummy;
  return Is_Acyclic(G,dummy);
}


void Make_Acyclic(graph& G)
{ list<edge> back;
  Is_Acyclic(G,back);
  edge e;
  forall(e,back) G.del_edge(e);
}



static void dfs(const graph& G, node v, node_array<bool>& reached, int&
count)
{ reached[v] = true;
  count++;
  edge e;
  forall_inout_edges(e,v)
  { node w = G.opposite(v,e);
    if ( !reached[w] ) dfs(G,w,reached,count);
   }
 }


bool Is_Connected(const graph& G)
{
  node_array <bool>  reached(G, false);
  int  count = 0;
  node s = G.first_node();

  if (s != nil)
    dfs(G,s,reached,count);

  return count == G.number_of_nodes();
 }


void Make_Connected(graph& G, list<edge>& L)
{
  node_array <bool>  reached(G, false);
  node u = G.first_node();
  int count = 0;
```

```
  node v;
  forall_nodes(v, G)
    if ( !reached[v] )
    { dfs(G,v,reached,count);  // explore connected comp with root v
      if (u != v)                       // link v's comp to the first comp
        L.append(G.new_edge(u, v));
     }
 }


list<edge> Make_Connected(graph& G)
{ list<edge> L;
  if (G.number_of_nodes() > 0) Make_Connected(G,L);
  return L;
 }



static void make_bicon_dfs(graph& G, node v, int& dfs_count,
                                list<edge>& L,
                                node_array<int>&  dfsnum,
                                node_array<int>&  lowpt,
                                node_array<node>& parent)
{ node u = nil;

  dfsnum[v] = dfs_count++;
  lowpt[v]  = dfsnum[v];

  edge e;
  forall_inout_edges(e,v)
  {
    node w = G.opposite(v,e);

    if (v == w) continue; // ignore loops

    if (u == nil) u = w;  // first child

    if ( dfsnum[w] == -1) // w not reached before; e is a tree edge
      {
        parent[w] = v;

        make_bicon_dfs(G, w, dfs_count, L, dfsnum, lowpt, parent);

        if (lowpt[w] == dfsnum[v])
        { // |v| is an articulation point. We now add an edge. If |w| is
the
        // first child and |v| has a parent then we connect |w| and
        // |parent[v]|, if |w| is a first child and |v| has no parent
then
        // we do nothing. If |w| is not the first child then we connect
|w|
        // to the first child. The net effect of all of this is to link
all
        // children of an articulation point to the first child and the
first
        // child to the parent (if it exists)

        if (w == u && parent[v])
```

```
            { L.append(G.new_edge(w, parent[v]));
            //L.append(G.new_edge(parent[v], w)); (if bidirected)
           }

          if (w != u)
          { L.append(G.new_edge(u, w));
            //L.append(G.new_edge(w, u)); (if bidirected)
           }
           }

           lowpt[v] = Min(lowpt[v], lowpt[w]);
         }
       else // non tree edge
        lowpt[v] = Min(lowpt[v], dfsnum[w]);

  }

}


static bool is_bicon_dfs(const graph& G, node v, int& dfs_count,
                                          node_array<int>&  dfsnum,
                                          node_array<int>&  lowpt,
                                          node_array<node>& parent)

{ node u = nil;
  edge e;

  dfsnum[v] = dfs_count++;
  lowpt[v]  = dfsnum[v];

  forall_inout_edges(e,v)
  { node w = G.opposite(v,e);
    if (u == nil) u = w;
    if ( dfsnum[w] == -1 )
      { parent[w] = v;
        if (!is_bicon_dfs(G, w, dfs_count, dfsnum, lowpt, parent))
return false;
        if (lowpt[w] == dfsnum[v] && (w != u || parent[v]))  return
false;
        lowpt[v] = Min(lowpt[v], lowpt[w]);
      }
    else
        lowpt[v] = Min(lowpt[v], dfsnum[w]);
  }

  return true;
}


bool Is_Biconnected(const graph & G)
{ if (G.empty()) return true;
  if ( ! Is_Connected(G) ) return false;
  node_array<int>  lowpt(G);
  node_array<int>  dfsnum(G,-1);
  node_array<node> parent(G,nil);
  int dfs_count = 0;
  return is_bicon_dfs(G, G.first_node(), dfs_count, dfsnum, lowpt,
parent);
}
```

```
void Make_Biconnected(graph& G, list<edge>& L)
{
  if (G.number_of_nodes() == 0) return;

  Make_Connected(G,L);

  node_array<int>  lowpt(G);
  node_array<int>  dfsnum(G,-1);  // dfsnum[v] == -1  <=>  v not reached
  node_array<node> parent(G,nil);

  int dfs_count = 0;

  make_bicon_dfs(G, G.first_node(), dfs_count, L, dfsnum, lowpt,
parent);
}


list<edge> Make_Biconnected(graph & G)
{ list<edge> L;
  Make_Biconnected(G,L);
  return L;
 }



static bool bi_bfs(const graph& G, node s, node_array<int>& side)
{
  list<node> Q;

  Q.append(s);
  side[s] = 0;

  while ( ! Q.empty() )
  { node v = Q.head();
    edge e;
    forall_inout_edges(e,v)
    { node w = G.opposite(v,e);
      if (side[v] == side[w]) return false;
      if (side[w] == -1)
      { Q.append(w);
        side[w] = 1 - side[v];
       }
     }
    Q.pop();
  }

  return true;
}


bool Is_Bipartite(const graph& G, list<node>& A, list<node>& B)
{
  node_array<int> side(G,-1);
  node v;
```

```
  forall_nodes(v,G)
    if (side[v] == -1)
        if (! bi_bfs(G,v,side)) return false;

  forall_nodes(v,G)
  { if (side[v] == 0) A.append(v);
    if (side[v] == 1) B.append(v);
   }

  return true;

 }


bool Is_Bipartite(const graph& G)
{ list<node> A,B;
  return Is_Bipartite(G,A,B);
}


int COMPONENTS(const graph&G, node_array<int>&);

int Genus(const graph& G)
{ int n = G.number_of_nodes();
  int m = G.number_of_edges()/2;  // G is bidirected

  edge_array<bool> considered(G,false);
  int f = 0;
  edge e;
  forall_edges(e,G)
  { if (G.reversal(e) == nil)
       error_handler(1,"Genus: graph must be a map.");
    if ( !considered[e] )
    { // trace the face to the left of e
      f++;
      edge x = e;
      do { considered[x] = true;
           x = G.face_cycle_succ(x);
         }
      while (x != e);
    }
  }

  node_array<int> cnum(G);
  int c = COMPONENTS(G,cnum)-1;

  return (2-n+m-f+c)/2;
}



/*
void copy_graph(const graph& G, GRAPH<node,edge>& H,
                node_array<node>& v_in_H, edge_array<edge>& e_in_H)
{

  node v;
  forall_nodes(v,G) v_in_H[v] = H.new_node(v);

  edge e;
```

```
  forall_edges(e,G) e_in_H[e] =
      H.new_edge(v_in_H[source(e)],v_in_H[target(e)],e);
}
*/


bool Is_Map(const graph& G)
{ edge_array<edge> rev(G);
  if (!Is_Bidirected(G,rev)) return false;
  edge x;
  forall_edges(x,G)
  { edge y = G.reversal(x);
    if (x != G.reversal(y)) return false;
    if (source(x) != target(y) || source(y) != target(x)) return false;
   }
  return true;
}


bool Is_Planar_Map(const graph& G) { return  Is_Map(G) &&Genus(G) == 0;
}

bool Is_Planar(const graph& G)
{ graph G1 = G;
  return PLANAR(G1);
 }
```

```
/***********************************************************************
********
+
+  LEDA 3.5.1
+
+  _g_objects.c
+
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+
************************************************************************
*******/
#include <LEDA/graph.h>


//----------------------------------------------------------------------
--------
// nodes and edges
//
// by S. Naeher  (1995)
//----------------------------------------------------------------------
--------


node_struct::node_struct(GenPtr inf)
{ data[0] = inf;
  owner = nil;
  id = 0;
  for(int j=0; j<2; j++)
  { first_adj_edge[j]= nil;
    last_adj_edge[j] = nil;
    adj_length[j] = 0;
  }
}

edge_struct::edge_struct(node v, node w, GenPtr i)
{ succ_adj_edge[0] = nil;
  succ_adj_edge[1] = nil;
  pred_adj_edge[0] = nil;
  pred_adj_edge[1] = nil;
  id = 0;
  term[0] = v;
  term[1] = w;
  rev = nil;
  data[0] = i;
}


face_struct::face_struct(GenPtr x)
{ data[0] = x ;
  id = 0;
  owner = nil;
  head = nil;
  sz = 0;
```

```
}


void node_struct::append_adj_edge(edge e,int i, int chain_e)
{ // append e to adj_list[i]
  // use succ/pred_adj_edge[chain_e] pointers for chaining of e

  edge last = last_adj_edge[i];

  e->succ_adj_edge[chain_e] = nil;

  if (last == 0) // empty list
  { first_adj_edge[i] = e;
    e->pred_adj_edge[chain_e] = nil;
   }
  else
  { e->pred_adj_edge[chain_e] = last;
    if (source(last) == target(last))  // loop
       last->succ_adj_edge[chain_e] = e;
    else
       last->succ_adj_edge[(this==source(last)) ? 0:1] = e;
   }

  last_adj_edge[i] = e;
  adj_length[i]++;

 }


void node_struct::insert_adj_edge(edge e, edge e1, int i, int chain_e,
int dir)
{
  // insert e after (dir==0) or before (dir!=0) e1 into adj_list[i]
  // use succ/pred_adj_edge[chain_e] pointers for chaining


  if (e1 == nil)
  { append_adj_edge(e,i,chain_e);
    return;
   }


  edge e2;        // successor (dir==0) or predecessor (dir!=0) of e1

  int  chain_e1; // chaining used for e1


  if (source(e1) == target(e1)) // e1 is a self-loop
      chain_e1 = chain_e;
  else
      chain_e1 = (this == source(e1)) ? 0 : 1;

  if (dir == 0)
  { e2 = e1->succ_adj_edge[chain_e1];
    e->pred_adj_edge[chain_e] = e1;
    e->succ_adj_edge[chain_e] = e2;
    e1->succ_adj_edge[chain_e1] = e;
    if (e2 == nil)
       last_adj_edge[i] = e;
```

```
      else
       { if (source(e2) == target(e2)) //loop
            e2->pred_adj_edge[chain_e] = e;
         else
            e2->pred_adj_edge[(this==source(e2)) ? 0:1] = e;
       }
    }
  else
  { e2 = e1->pred_adj_edge[chain_e1];
    e->succ_adj_edge[chain_e] = e1;
    e->pred_adj_edge[chain_e] = e2;
    e1->pred_adj_edge[chain_e1] = e;
    if (e2 == nil)
       first_adj_edge[i] = e;
    else
     { if (source(e2) == target(e2)) //loop
          e2->succ_adj_edge[chain_e] = e;
       else
          e2->succ_adj_edge[(this==source(e2)) ? 0:1] = e;
     }
   }

   adj_length[i]++;
}


void node_struct::del_adj_edge(edge e, int i, int chain_e)
{
  // remove e from adj_list[i]
  // with respect to succ/pred_adj_edge[chain_e] pointers

  edge e_succ = e->succ_adj_edge[chain_e];
  edge e_pred = e->pred_adj_edge[chain_e];

  if (e_succ)
      if (source(e_succ) == target(e_succ)) // loop
         e_succ->pred_adj_edge[chain_e] = e_pred;
      else
         e_succ->pred_adj_edge[(this==source(e_succ)) ? 0:1 ] = e_pred;
  else
      last_adj_edge[i] = e_pred;

  if (e_pred)
      if (source(e_pred) == target(e_pred)) // loop
         e_pred->succ_adj_edge[chain_e] = e_succ;
      else
         e_pred->succ_adj_edge[(this==source(e_pred)) ? 0:1 ] = e_succ;
  else
      first_adj_edge[i] = e_succ;

  adj_length[i]--;
 }




void graph_obj_list::clear()
{ obj_list_head = 0;
```

```
  obj_list_tail = 0;
  obj_list_sz   = 0;
}


void graph_obj_list::append(graph_object* e)
{
  e->obj_list_succ = 0;

  if (obj_list_sz > 0)
     obj_list_tail->obj_list_succ = e;
  else
     obj_list_head = e;

  e->obj_list_pred = obj_list_tail;
  obj_list_tail = e;

  obj_list_sz++;
}


graph_object* graph_obj_list::pop()
{ graph_object* e = obj_list_head;
  if (e)
  { graph_object* s = e->obj_list_succ;
    obj_list_head = s;
    if (s)
       s->obj_list_pred = 0;
    else
       obj_list_tail = 0;
    obj_list_sz--;
   }
  return e;
}


void graph_obj_list::remove(graph_object* e)
{
  graph_object* s = e->obj_list_succ;
  graph_object* p = e->obj_list_pred;

  if (s)
    { e->obj_list_succ = s->obj_list_succ;
      s->obj_list_pred = p; }
  else
      obj_list_tail = p;

  if (p)
    { e->obj_list_pred = p->obj_list_pred;
      p->obj_list_succ = s; }
  else
      obj_list_head = s;

  obj_list_sz--;
}


void graph_obj_list::conc(graph_obj_list& L)
{ if (L.obj_list_sz ==0) return;

  if (obj_list_sz > 0)
```

```
      obj_list_tail->obj_list_succ = L.obj_list_head;
   else
      obj_list_head = L.obj_list_head;
   L.obj_list_head->obj_list_pred = obj_list_tail;
   obj_list_tail = L.obj_list_tail;
   obj_list_sz += L.obj_list_sz;
   L.clear();
}
```

```
/*******************************************************************************
********
+
+  LEDA 3.5.1
+
+  _g_partition.c
+
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+  used free of charge in academic research and teaching. Any commercial
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+
********************************************************************************
*******/
#include <LEDA/node_partition.h>

void node_partition::init(const graph& G)
{ node v;
  forall_nodes(v,G) ITEM[v] = partition::make_block(v);
 }
```

```
/*******************************************************************************
+
+  LEDA 3.5.1
+
+  _g_random.c
+
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+
*******************************************************************************/
#include <LEDA/graph.h>
#include <LEDA/ugraph.h>

//-----------------------------------------------------------------------------
// generators for random graphs
//
// S. Naeher
//-----------------------------------------------------------------------------


// we use the global random integer source "rand_int"

void random_graph(graph& G, int n, int m)
{ /* random graph with n nodes and m edges */

  node*  V = new node[n];
  int* deg = new int[n];
  int i;

  G.clear();

  for(i=0; i<n; i++)
  { V[i] = G.new_node();
    deg[i] = 0;
   }

  for(i=0; i<m; i++) deg[rand_int(0,n-1)]++;

  for(i=0; i<n; i++)
  { node v = V[i];
    int  d = deg[i];
    while (d--) G.new_edge(v,V[rand_int(0,n-1)]);
   }

  delete[] V;
  delete[] deg;
}


void random_ugraph(ugraph& G, int n, int m)
```

```
{ int i;
  node* V = new node[n];

  G.clear();

  for(i=0;i<n;i++) V[i] = G.new_node();

  while (m--) G.new_edge(V[rand_int(0,n-1)],V[rand_int(0,n-1)]);
}


void random_bigraph(graph& G,int n1,int n2,int m,list<node>&
A,list<node>& B)
{
   int  d = m/n1;
   int  r = m%n1;

   node* AV = new node[n1];
   node* BV = new node[n2];

   A.clear();
   B.clear();
   G.clear();

   for(int a = 0; a < n1; a++)  A.append(AV[a] = G.new_node());
   for(int b = 0; b < n2; b++)  B.append(BV[b] = G.new_node());

   node v;
   int i;

   forall(v,A)
     for(i=0;i<d;i++)
       G.new_edge(v,BV[rand_int(0,n2-1)]);

   while (r--) G.new_edge(AV[rand_int(0,n1-1)], BV[rand_int(0,n2-1)]);

   delete[] AV;
   delete[] BV;
}



//----------------------------------------------------------------------
--------
// random planar graph
//----------------------------------------------------------------------
--------

#include <LEDA/sortseq.h>
#include <LEDA/prio.h>
#include <math.h>

#define YNIL seq_item(nil)
#define XNIL pq_item(nil)


#define EPS  0.00001
#define EPS2 0.0000000001

class POINT;
```

```
class SEGMENT;
typedef POINT* point;
typedef SEGMENT* segment;

enum point_type {Intersection=0,Rightend=1,Leftend=2};

class POINT
{
  friend class SEGMENT;

  segment seg;
  int     kind;
  double  x;
  double  y;

  public:

  POINT(double a,double b)
  {
    x=a; y=b; seg=0; kind=Intersection;
   }


  LEDA_MEMORY(POINT);

  friend double    get_x(point p)     { return p->x; }
  friend double    get_y(point p)     { return p->y; }
  friend int       get_kind(point p) { return p->kind; }
  friend segment get_seg(point p)   { return p->seg; }

  friend bool intersection(segment, segment, point&);
};


static int compare(const point& p1, const point& p2)
{ if (p1==p2) return 0;

  double diffx = get_x(p1) - get_x(p2);
  if (diffx >  EPS2 ) return  1;
  if (diffx < -EPS2 ) return -1;

  int    diffk = get_kind(p1)-get_kind(p2);
  if (diffk != 0) return diffk;

  double diffy = get_y(p1) - get_y(p2);
  if (diffy >  EPS2 ) return  1;
  if (diffy < -EPS2 ) return -1;

  return 0;

}


class SEGMENT
{
  point startpoint;
  point endpoint;
  double  slope;
  double  yshift;
  node  left_node;
```

```
  int   orient;
  int   color;
  int   name;


  public:

  SEGMENT(point, point,int,int);

 ~SEGMENT() { delete startpoint; delete endpoint; }

  LEDA_MEMORY(SEGMENT);


  friend point get_startpoint(segment seg)     { return seg->startpoint;
}
  friend point get_endpoint(segment seg)       { return seg->endpoint; }
  friend double get_slope(segment seg)           { return seg->slope; }
  friend double get_yshift(segment seg)          { return seg->yshift; }
  friend node get_left_node(segment seg)         { return seg-
>left_node; }
  friend void set_left_node(segment seg, node v) { seg->left_node = v; }

  friend bool intersection(segment, segment, point&);
};



SEGMENT::SEGMENT(point p1,point p2,int c, int n)
  {
    left_node  = nil;
    color      = c;
    name       = n;

    if (compare(p1,p2) < 0)
     { startpoint = p1;
       endpoint = p2;
       orient = 0;
      }
    else
     { startpoint = p2;
       endpoint = p1;
       orient = 1;
      }

    startpoint->kind = Leftend;
    endpoint->kind = Rightend;
    startpoint->seg = this;
    endpoint->seg = this;

    if (endpoint->x != startpoint->x)
    {
      slope = (endpoint->y - startpoint->y)/(endpoint->x - startpoint-
>x);
      yshift = startpoint->y - slope * startpoint->x;

      startpoint->x -= EPS;
      startpoint->y -= EPS * slope;
      endpoint->x += EPS;
      endpoint->y += EPS * slope;
```

```
    }
    else //vertical segment
    { startpoint->y -= EPS;
      endpoint->y   += EPS;
      slope = 0;
      yshift = 0;
     }
  }


static double x_sweep;
static double y_sweep;


static int compare(const segment& s1, const segment& s2)
{
  double y1 = get_slope(s1)*x_sweep+get_yshift(s1);
  double y2 = get_slope(s2)*x_sweep+get_yshift(s2);

  double diff = y1-y2;
  if (diff >  EPS2 ) return  1;
  if (diff < -EPS2 ) return -1;

  if (get_slope(s1) == get_slope(s2))
        return compare(get_x(get_startpoint(s1)),
get_x(get_startpoint(s2)));

  if (y1 <= y_sweep+EPS2)
        return compare(get_slope(s1),get_slope(s2));
  else
        return compare(get_slope(s2),get_slope(s1));

}



static priority_queue<seq_item,point> X_structure;

static sortseq&lt;segment,pq_item&gt; Y_structure;


bool intersection(segment seg1,segment seg2, point& inter)
{
  if (seg1->slope == seg2->slope)
    return false;
  else
  {
    double cx = (seg2->yshift - seg1->yshift) / (seg1->slope - seg2-
>slope);

    if (cx <= x_sweep) return false;

    if (seg1->startpoint->x > cx || seg2->startpoint->x > cx ||
        seg1->endpoint->x < cx || seg2->endpoint->x < cx ) return false;

    inter = new POINT(cx,seg1->slope * cx + seg1->yshift);

    return true;
  }
}
```

```
inline pq_item Xinsert(seq_item i, point p)
{ return X_structure.insert(i,p); }


inline point Xdelete(pq_item i)
{ point p = X_structure.inf(i);
  X_structure.del_item(i);
  return p;
 }



void random_planar_graph(graph& G, node_array<double>& xcoord,
                                   node_array<double>& ycoord, int n)
{
  point    p,inter;
  segment  seg, l,lsit,lpred,lsucc,lpredpred;
  pq_item  pqit,pxmin;
  seq_item sitmin,sit,sitpred,sitsucc,sitpredpred;

  int MAX_X = n;
  int MAX_Y = n;


  int N = n;  // number of random segments

  G.clear();

  xcoord.init(G,n,0);
  ycoord.init(G,n,0);


  int count=1;

  //initialization of the X-structure

  for (int i = 0; i < N; i++)
   { //point p = new POINT(rand_int(0,MAX_X/3), rand_int(0,MAX_Y));
     //point q = new POINT(rand_int(2*MAX_X/3,MAX_X),
rand_int(0,MAX_Y));
     point p = new POINT(rand_int(0,MAX_X), rand_int(0,MAX_Y));
     point q = new POINT(rand_int(0,MAX_X), rand_int(0,MAX_Y));
     seg = new SEGMENT(p,q,0,count++);
     Xinsert(YNIL,get_startpoint(seg));
   }

  x_sweep = -MAXINT;
  y_sweep = -MAXINT;

  while( !X_structure.empty()  && G.number_of_nodes() < n )
  {
    pxmin = X_structure.find_min();
    p = X_structure.inf(pxmin);

    sitmin = X_structure.key(pxmin);

    Xdelete(pxmin);

    if (sitmin == YNIL) //left endpoint
```

```
{
  l = get_seg(p);
  x_sweep = get_x(p);
  y_sweep = get_y(p);

  node w = G.new_node();
  xcoord[w] = x_sweep;
  ycoord[w] = y_sweep;
  set_left_node(l,w);

  sit = Y_structure.insert(l,XNIL);

  Xinsert(sit,get_endpoint(l));

  sitpred = Y_structure.pred(sit);
  sitsucc = Y_structure.succ(sit);

  if (sitpred != YNIL)
  { if ((pqit = Y_structure.inf(sitpred)) != XNIL)
      delete Xdelete(pqit);

    lpred = Y_structure.key(sitpred);

    Y_structure.change_inf(sitpred,XNIL);

    if (intersection(lpred,l,inter))
        Y_structure.change_inf(sitpred,Xinsert(sitpred,inter));
  }


  if (sitsucc != YNIL)
  { lsucc = Y_structure.key(sitsucc);
    if (intersection(lsucc,l,inter))
       Y_structure.change_inf(sit,Xinsert(sit,inter));
  }

}
else if (get_kind(p) == Rightend)
     //right endpoint
     {
       x_sweep = get_x(p);
       y_sweep = get_y(p);

       sit = sitmin;

       sitpred = Y_structure.pred(sit);
       sitsucc = Y_structure.succ(sit);

       segment seg = Y_structure.key(sit);

       Y_structure.del_item(sit);

       delete seg;

       if((sitpred != YNIL)&&(sitsucc != YNIL))
       {
         lpred = Y_structure.key(sitpred);
         lsucc = Y_structure.key(sitsucc);
         if (intersection(lsucc,lpred,inter))
            Y_structure.change_inf(sitpred,Xinsert(sitpred,inter));
       }
```

```
}
else // intersection point p
{
  node w = G.new_node();
  xcoord[w] = get_x(p);
  ycoord[w] = get_y(p);

  /* Let L = list of all lines intersecting in p

     we compute sit     = L.head();
     and        sitpred = L.tail();

     by scanning the Y_structure in both directions
     starting at sitmin;

  */

  /* search for sitpred upwards from sitmin: */

  Y_structure.change_inf(sitmin,XNIL);

  sitpred = Y_structure.succ(sitmin);


  while ((pqit=Y_structure.inf(sitpred)) != XNIL)
  { point q = X_structure.inf(pqit);
    if (compare(p,q) != 0) break;
    X_structure.del_item(pqit);
    Y_structure.change_inf(sitpred,XNIL);
    sitpred = Y_structure.succ(sitpred);
   }


  /* search for sit downwards from sitmin: */

  sit = sitmin;

  seq_item sit1;

  while ((sit1=Y_structure.pred(sit)) != YNIL)
  { pqit = Y_structure.inf(sit1);
    if (pqit == XNIL) break;
    point q = X_structure.inf(pqit);
    if (compare(p,q) != 0) break;
    X_structure.del_item(pqit);
    Y_structure.change_inf(sit1,XNIL);
    sit = sit1;
   }



  // insert edges to p for all segments in sit, ..., sitpred
into G
  // and set left node to w

  lsit = Y_structure.key(sitpred);

  node v = get_left_node(lsit);
  if (v!=nil && w!=nil) G.new_edge(v,w);
  set_left_node(lsit,w);
```

```
          for(sit1=sit; sit1!=sitpred; sit1 = Y_structure.succ(sit1))
          { lsit = Y_structure.key(sit1);

            v = get_left_node(lsit);
            if (v!=nil && w!=nil) G.new_edge(v,w);
            set_left_node(lsit,w);
           }

          lsit = Y_structure.key(sit);
          lpred=Y_structure.key(sitpred);
          sitpredpred = Y_structure.pred(sit);
          sitsucc=Y_structure.succ(sitpred);


          if (sitpredpred != YNIL)
           {
             lpredpred=Y_structure.key(sitpredpred);

             if ((pqit = Y_structure.inf(sitpredpred)) != XNIL)
               delete Xdelete(pqit);

             Y_structure.change_inf(sitpredpred,XNIL);


             if (intersection(lpred,lpredpred,inter))
               Y_structure.change_inf(sitpredpred,
                                           Xinsert(sitpredpred,inter));
            }


          if (sitsucc != YNIL)
           {
             lsucc=Y_structure.key(sitsucc);

             if ((pqit = Y_structure.inf(sitpred)) != XNIL)
               delete Xdelete(pqit);

             Y_structure.change_inf(sitpred,XNIL);

             if (intersection(lsucc,lsit,inter))
                 Y_structure.change_inf(sit,Xinsert(sit,inter));
            }

// reverse the subsequence sit, ... ,sitpred  in the Y_structure

          x_sweep = get_x(p);
          y_sweep = get_y(p);

          Y_structure.reverse_items(sit,sitpred);

         delete p;

        } // intersection

   }


   pq_item xit;
   forall_items(xit,X_structure)
   { point      p = X_structure.inf(xit);
```

```
    seq_item sit = X_structure.key(xit);
    if (get_kind(p) == Leftend)          delete get_seg(p);
    if (get_kind(p) == Rightend && sit) delete Y_structure.key(sit);
    if (get_kind(p) == Intersection)    delete p;
   }

  X_structure.clear();
  Y_structure.clear();

  Make_Connected(G);

  // normalize x and y coordinates
  node v;
  forall_nodes(v,G)
  { xcoord[v] /= x_sweep;
    ycoord[v] /= n;
   }
}


void random_planar_graph(graph& G, int n)
{ node_array<double> xcoord;
  node_array<double> ycoord;
  random_planar_graph(G,xcoord,ycoord,n);
  //random_planar_graph(G,n,n);
  //Make_Connected(G);
 }




void maximal_planar_map(graph& G, int n)
{
  G.clear();

  if (n <= 0 ) return;

  node a = G.new_node();
  n--;

  if (n == 0) return;

  node b = G.new_node();
  n--;

  edge* E = new edge[6*n];

  E[0] = G.new_edge(a,b);
  E[1] = G.new_edge(b,a);
  G.set_reversal(E[0],E[1]);

  int m = 2;

  while (n--)
  { edge e = E[rand_int(0,m-1)];
    node v = G.new_node();
    while (target(e) != v)
    { edge x = G.new_edge(v,source(e));
      edge y = G.new_edge(e,v,after);
```

```
      E[m++] = x;
      E[m++] = y;
      G.set_reversal(x,y);
      e = G.face_cycle_succ(e);
     }
   }

  delete[] E;
}


void maximal_planar_graph(graph& G, int n)
{
  maximal_planar_map(G,n);
  list<edge> E;

  edge_array<bool> marked(G,false);
  edge e;
  forall_edges(e,G)
  { if (!marked[e]) E.append(e);
    marked[e] = true;
    marked[G.reversal(e)] = true;
   }

  forall(e,E) G.del_edge(e);
}



void random_planar_map(graph& G, int n, int m)
{
  maximal_planar_map(G,n);

 list<edge> E;

 edge_array<bool> marked(G,false);
 edge e;
 forall_edges(e,G)
 { if (!marked[e]) E.append(e);
   marked[e] = true;
   marked[G.reversal(e)] = true;
  }


 E.permute();

 while (E.length() > m)
 { edge e = E.pop();
   edge r = G.reversal(e);
   G.del_edge(e);
   G.del_edge(r);
  }

}


void random_planar_graph(graph& G, int n, int m)
{
  random_planar_map(G,n,m);
  list<edge> E;
```

```
  edge_array<bool> marked(G,false);
  edge e;
  forall_edges(e,G)
  { if (!marked[e]) E.append(e);
    marked[e] = true;
    marked[G.reversal(e)] = true;
   }

  forall(e,E) G.del_edge(e);
}
```

```
/*******************************************************************************
********
+
+  LEDA 3.5.1
+
+  _g_sort.c
+
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+
*******************************************************************************
*******/
#include <LEDA/graph.h>

//-----------------------------------------------------------------------------
----
// sorting
//
// by S. Naeher  (1995)
//-----------------------------------------------------------------------------
--------


static const graph_map*  NA;

static graph* GGG;


/*
static int array_cmp_nodes(const node& x, const node& y)
{ return NA->cmp_entry(NA->array_read(x),NA->array_read(y)); }

static int array_cmp_edges(const edge& x, const edge& y)
{ return NA->cmp_entry(NA->array_read(x),NA->array_read(y)); }
*/

static int int_array_cmp_nodes(const node& x, const node& y)
{ return LEDA_COMPARE(int,NA->array_read(x),NA->array_read(y)); }

static int int_array_cmp_edges(const edge& x, const edge& y)
{ return LEDA_COMPARE(int,NA->array_read(x),NA->array_read(y)); }

static int float_array_cmp_nodes(const node& x, const node& y)
{ return LEDA_COMPARE(float,NA->array_read(x),NA->array_read(y)); }

static int float_array_cmp_edges(const edge& x, const edge& y)
{ return LEDA_COMPARE(float,NA->array_read(x),NA->array_read(y)); }

static int double_array_cmp_nodes(const node& x, const node& y)
{ return LEDA_COMPARE(double,NA->array_read(x),NA->array_read(y)); }

static int double_array_cmp_edges(const edge& x, const edge& y)
{ return LEDA_COMPARE(double,NA->array_read(x),NA->array_read(y)); }
```

```
static int graph_cmp_nodes(const node& x, const node& y)
{ return GGG->cmp_node_entry(x,y); }

static int graph_cmp_edges(const edge& x, const edge& y)
{ return GGG->cmp_edge_entry(x,y); }


void graph::sort_nodes(const list<node>& vl)
{
  if (vl.length() != number_of_nodes())
       error_handler(1,"graph::sort_nodes(list<node>): illegal node
list");

  v_list.clear();

  node v;
  forall(v,vl)
  { if (v->owner != this)
       error_handler(1,"graph::sort_nodes(list<node>): illegal node
list");
    v_list.append(v);
   }
 }



void graph::sort_nodes(int (*f)(const node&, const node&))
{ list<node> vl = all_nodes();
  vl.sort(f);
  sort_nodes(vl);
}


void graph::sort_edges(const list<edge>& el)
{
  node v;
  edge e;

  if (el.length() != number_of_edges())
      error_handler(1,"graph::sort_edges(list<edge>): illegal edge
list");


  // clear all adjacency lists
  forall_nodes(v,*this)
    for(int i=0; i<2; i++)
    { v->first_adj_edge[i] = 0;
      v->last_adj_edge[i] = 0;
      v->adj_length[i] = 0;
     }

  e_list.clear();

  forall(e,el)
  {
    if (e->term[0]->owner != this)
        error_handler(1,"graph::sort_edges(list<edge>): edge not in
graph");
```

```
    e_list.append(e);

    source(e)->append_adj_edge(e,0,0);
    if (undirected)
       target(e)->append_adj_edge(e,0,1);
    else
       target(e)->append_adj_edge(e,1,1);
   }
 }


void graph::sort_edges(int (*f)(const edge&, const edge&))
{ list<edge> el = all_edges();
  el.sort(f);
  sort_edges(el);
 }


void graph::sort_nodes(const graph_map& A)
{ NA = &A;
  switch (A.elem_type_id()) {

  case INT_TYPE_ID: sort_nodes(int_array_cmp_nodes);
                    break;
  case FLOAT_TYPE_ID:
                    sort_nodes(float_array_cmp_nodes);
                    break;
  case DOUBLE_TYPE_ID:
                    sort_nodes(double_array_cmp_nodes);
                    break;
  default:
          error_handler(1,"G.sort_nodes(node_array<T>): T must be
numerical.");
  }
 }


void graph::sort_edges(const graph_map& A)
{ NA = &A;
  switch (A.elem_type_id()) {

  case INT_TYPE_ID: sort_edges(int_array_cmp_edges);
                    break;
  case FLOAT_TYPE_ID:
                    sort_edges(float_array_cmp_edges);
                    break;
  case DOUBLE_TYPE_ID:
                    sort_edges(double_array_cmp_edges);
                    break;
  default:
          error_handler(1,"G.sort_edges(node_array<T>): T must be
numerical.");
  }
 }


void graph::sort_nodes()
{ GGG = this;
  sort_nodes(graph_cmp_nodes);
 }
```

```
void graph::sort_edges()
{ GGG = this;
  sort_edges(graph_cmp_edges);
 }



// bucket sort

static int array_ord_node(const node& x)
{ return LEDA_ACCESS(int,NA->array_read(x)); }

static int array_ord_edge(const edge& x)
{ return LEDA_ACCESS(int,NA->array_read(x)); }


void graph::bucket_sort_nodes(int l, int h, int (*ord)(const node&))
{ list<node> vl = all_nodes();
  vl.bucket_sort(l,h,ord);
  sort_nodes(vl);
}

void graph::bucket_sort_edges(int l, int h, int (*ord)(const edge&))
{ list<edge> el = all_edges();
  el.bucket_sort(l,h,ord);
  sort_edges(el);
 }

void graph::bucket_sort_nodes(int (*ord)(const node&))
{ list<node> vl = all_nodes();
  vl.bucket_sort(ord);
  sort_nodes(vl);
}

void graph::bucket_sort_edges(int (*ord)(const edge&))
{ list<edge> el = all_edges();
  el.bucket_sort(ord);
  sort_edges(el);
 }


void graph::bucket_sort_nodes(const graph_map& A)
{ NA = &A;
  switch (A.elem_type_id()) {

  case INT_TYPE_ID: bucket_sort_nodes(array_ord_node);
                    break;
  default:
    error_handler(1,"G.bucket_sort_nodes(node_array<T>): T must be
integer.");
  }
 }


void graph::bucket_sort_edges(const graph_map& A)
{ NA = &A;
  switch (A.elem_type_id()) {

  case INT_TYPE_ID: bucket_sort_edges(array_ord_edge);
```

```
                         break;
  default:
    error_handler(1,"G.bucket_sort_edges(edge_array<T>): T must be
integer.");
  }
 }
```

```
/****************************************************************************
********
+
+  LEDA 3.5.1
+
+  _gml_graph.c
+
+  This file is part of the LEDA research version (LEDA-R) that can be
+  used free of charge in academic research and teaching. Any commercial
+  use of this software requires a license which is distributed by the
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+
*****************************************************************************
*******/
//------------------------------------------------------------------------- //
// class gml_graph, parser for graphs in GML format                          //
//                                                                           //
// by David Alberts (1997)                                                   //
//------------------------------------------------------------------------- //

#include<LEDA/gml_graph.h>


void gml_graph::init_rules()
{
  // graph rule
  append("graph");
  add_rule(new_graph,gml_list);

  // directed graph (default) or not?
  append("directed");
  add_rule(directed,gml_int);
  goback();

  // type of node parameter (optional)
  append("nodeType");
  add_rule(nodeType,gml_string);
  goback();

  // type of edge parameter (optional)
  append("edgeType");
  add_rule(edgeType,gml_string);
  goback();

  // new node
  append("node");
  add_rule(new_node,gml_list);

  // node index
  append("id");
  add_rule(node_index,gml_int);
  goback();

  // node parameter
  append("parameter");
  add_rule(node_param,gml_string);
```

```
  goback();

  goback();

  // new edge
  append("edge");
  add_rule(new_edge,gml_list);

  // edge source
  append("source");
  add_rule(edge_source,gml_int);
  goback();

  // edge target
  append("target");
  add_rule(edge_target,gml_int);
  goback();

  // edge parameter
  append("parameter");
  add_rule(edge_param,gml_string);

  reset_path();
}

void gml_graph::add_graph_rule(gml_graph_rule f, gml_value_type t, char*
key)
{
  if(key)
  {
    reset_path();
    append("graph");
    append(key);
  }

  graph_rules[next_rule] = f;
  add_rule(next_rule,t);
  next_rule++;

  if(key) reset_path();
}

void gml_graph::add_node_rule(gml_node_rule f, gml_value_type t, char*
key)
{
  if(key)
  {
    reset_path();
    append("graph");
    append("node");
    append(key);
  }

  node_rules[next_rule] = f;
  add_rule(next_rule,t);
  next_rule++;

  if(key) reset_path();
}
```

```
void gml_graph::add_edge_rule(gml_edge_rule f, gml_value_type t, char*
key)
{
  if(key)
  {
    reset_path();
    append("graph");
    append("edge");
    append(key);
  }

  edge_rules[next_rule] = f;
  add_rule(next_rule,t);
  next_rule++;

  if(key) reset_path();
}


bool gml_graph::interpret(gml_rule r, const gml_object* gobj)
{
  bool ok = true;

  switch(r)
  {
    case new_graph:
    {
      ok = graph_intro(gobj);
      break;
    }
    case directed:
    {
      if(gobj->get_int()) the_graph->make_directed();
      else                the_graph->make_undirected();
      break;
    }
    case nodeType:
    {
      right_node_type = !strcmp(the_graph->node_type(),gobj-
>get_string());
      break;
    }
    case edgeType:
    {
      right_edge_type = !strcmp(the_graph->edge_type(),gobj-
>get_string());
      break;
    }
    case new_node:
    {
      current_node = the_graph->new_node();
      has_id = false;
      gml_node_rule f;
      forall(f,new_node_rules) ok = ok &&
(*f)(gobj,the_graph,current_node);
      break;
    }
    case node_index:
    {
      (*(node_by_id))[gobj->get_int()] = current_node;
      has_id = true;
```

```
      break;
    }
    case node_param:
    {
      the_graph->set_node_entry(current_node,string(gobj-
>get_string()));
      break;
    }
    case new_edge:
    {
      edge e = the_graph->new_edge(dummy1,dummy2);
      (*(edge_s))[e] = -1;
      (*(edge_t))[e] = -1;
      current_edge = e;
      gml_edge_rule f;
      forall(f,new_edge_rules) ok = ok &&
(*f)(gobj,the_graph,current_edge);
      break;
    }
    case edge_source:
    {
      (*(edge_s))[current_edge] = gobj->get_int();
      break;
    }
    case edge_target:
    {
      (*(edge_t))[current_edge] = gobj->get_int();
      break;
    }
    case edge_param:
    {
      the_graph->set_edge_entry(current_edge,string(gobj-
>get_string()));
      break;
    }
    default:
    {
      if(node_rules.defined(r))
      {
        ok = (*(node_rules[r]))(gobj,the_graph,current_node);
        break;
      }
      if(edge_rules.defined(r))
      {
        ok = (*(edge_rules[r]))(gobj,the_graph,current_edge);
        break;
      }
      if(graph_rules.defined(r))
      {
        ok = (*(graph_rules[r]))(gobj,the_graph);
        break;
      }
      break;
    }
  }

  return ok;
}

bool gml_graph::list_end(gml_rule r, const gml_object* gobj)
{
```

```
  bool ok = true;

  switch(r)
  {
    case new_graph:
    {
      ok = graph_end(gobj);
      break;
    }
    case new_node:
    {
      if(!has_id)
      {
        print_error(*gobj,"missing node id");
        ok = false;
      }

      gml_node_rule f;
      forall(f,node_done_rules) ok = ok &&
(*f)(gobj,the_graph,current_node);

      current_node = nil;

      break;
    }
    case new_edge:
    {
      ok = edge_end(gobj);
      break;
    }
    default:
    {
      break;
    }
  }

  return ok;
}


bool gml_graph::graph_intro(const gml_object* gobj)
{
  node_by_id = new map<int,node>;
  edge_s = new map<edge,int>;
  edge_t = new map<edge,int>;

  the_graph->clear();
  dummy1 = the_graph->new_node();
  dummy2 = the_graph->new_node();

  right_node_type = true;
  right_edge_type = true;

  // call new graph rules
  bool ok = true;
  gml_graph_rule f;
  forall(f,new_graph_rules) ok = ok && (*f)(gobj,the_graph);

  return ok;
}
```

```
bool gml_graph::graph_end(const gml_object* gobj)
{
  bool ok = true;

  if(!right_node_type || !right_edge_type)
  {
    if(!right_node_type)
      print_error(*gobj,"wrong node type");
    if(!right_edge_type)
      print_error(*gobj,"wrong edge type");
    ok = false;
  }

  edge e;
  node s,t;
  // settle edges
  forall_edges(e,*the_graph)
  {
    s = t = 0;
    if((*(edge_s))[e] != -1)
      s = (*(node_by_id))[(*(edge_s))[e]];
    if((*(edge_t))[e] != -1)
      t = (*(node_by_id))[(*(edge_t))[e]];
    if(s && t) the_graph->move_edge(e,s,t);
  }

  the_graph->del_node(dummy1);
  the_graph->del_node(dummy2);

  // call graph done rules
  gml_graph_rule f;
  forall(f,graph_done_rules) ok = ok && (*f)(gobj,the_graph);

  if(node_by_id)
  {
    delete node_by_id;
    delete edge_s;
    delete edge_t;

    node_by_id = 0;
    edge_s = 0;
    edge_t = 0;
  }

  return ok;
}


bool gml_graph::edge_end(const gml_object* gobj)
{
  bool ok = true;

  if((*(edge_s))[current_edge] == -1)
  {
    print_error(*gobj,"edge without source");
    ok = false;
  }
  if((*(edge_t))[current_edge] == -1)
  {
    print_error(*gobj,"edge without target");
```

```
    ok = false;
  }

  gml_edge_rule f;
  forall(f,edge_done_rules) ok = ok &&
(*f)(gobj,the_graph,current_edge);

  current_edge = nil;

  return ok;
}
```

```
/*******************************************************************
********
+
+  LEDA 3.5.1
+
+  _graph.c
+
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+
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+  All rights reserved.
+
*******************************************************************
*******/
#include <LEDA/graph.h>

//-----------------------------------------------------------------
--------
// basic graph operations
//
// by S. Naeher (1995,1996)
//-----------------------------------------------------------------
--------

graph::graph()
{ int sz1 = LEDA::node_data_slots;
  int sz2 = LEDA::edge_data_slots;
  max_n_index = -1;
  max_e_index = -1;
  max_f_index = -1;
  parent = 0;
  undirected = false;
  data_sz[0] = sz1;
  data_sz[1] = sz2;
  data_sz[2] = 0;
  while (sz1) free_data[0].push(sz1--);
  while (sz2) free_data[1].push(sz2--);
  node_data_map = new graph_map(this,0);
  edge_data_map = new graph_map(this,1);
  adj_iterator  = new graph_map(this,0,0);
  FaceOf = 0;
 }


graph::graph(int sz1, int sz2)
{ max_n_index = -1;
  max_e_index = -1;
  max_f_index = -1;
  parent = 0;
  undirected = false;
  data_sz[0] = sz1;
  data_sz[1] = sz2;
  data_sz[2] = 0;
  while (sz1) free_data[0].push(sz1--);
  while (sz2) free_data[1].push(sz2--);
  node_data_map = new graph_map(this,0);
```

```
  edge_data_map = new graph_map(this,1);
  adj_iterator = new graph_map(this,0,0);
  FaceOf = 0;
 }


void graph::copy_all_entries() const
{ node v;
  forall_nodes(v,*this) copy_node_entry(v->data[0]);
  edge e;
  forall_edges(e,*this) copy_edge_entry(e->data[0]);
  // hidden edges
  for(e = (edge)h_list.head(); e; e = (edge)h_list.succ(e))
    copy_edge_entry(e->data[0]);
}


void graph::clear_all_entries() const
{ node v;
  forall_nodes(v,*this) clear_node_entry(v->data[0]);
  edge e;
  forall_edges(e,*this) clear_edge_entry(e->data[0]);
  // hidden edges
  for(e = (edge)h_list.head(); e; e = (edge)h_list.succ(e))
    clear_edge_entry(e->data[0]);
}



void graph::copy_graph(const graph& G)
{
  int n = G.number_of_nodes();
  //int m = G.number_of_edges();

  for(int k = 0; k < 3; k++)
  { data_sz[k] = G.data_sz[k];
    for(int i=1; i<=data_sz[k]; i++) free_data[k].append(i);
   }

  max_n_index = -1;
  max_e_index = -1;
  max_f_index = -1;

  e_list.clear();

  FaceOf = 0;

  parent = 0;

  if (n == 0) return;

  node* node_vec = new node[G.max_n_index+1];
  edge* edge_vec = new edge[G.max_e_index+1];

  if (node_vec == 0 || edge_vec == 0)
    error_handler(1," copy_graph: out of memory");

  // allocate a single block of memory for all nodes
  // memory_allocate_block(sizeof(node_struct),n);

  node v;
```

```
  forall_nodes(v,G)
     node_vec[index(v)] = new_node(v->data[0]);

  // allocate a single block of memory for all edges
  // memory_allocate_block(sizeof(edge_struct),m);

  bool loops_deleted = false;

  forall_nodes(v,G)
  { node a = node_vec[index(v)];
    edge e;
    forall_adj_edges(e,v)
    { if ( undirected && v == target(e)) //incoming edge
        { if (v == source(e)) // loop
            loops_deleted = true;
         }
       else
        { node b = node_vec[index(target(e))];
          edge_vec[index(e)] = new_edge(a,b,e->data[0]);
         }
     }
   }


  // update reversal information
  edge e;
  forall_edges(e,G)
    if (e->rev)
        edge_vec[index(e)]->rev = edge_vec[index(e->rev)];


  // copy faces (if existing)
  face f;
  forall_faces(f,G)
  { face f1 = new_face(f->data[0]);
    f1->head = edge_vec[index(f->head)];
   }

  delete[] node_vec;
  delete[] edge_vec;

  if ( loops_deleted )
      error_handler(0,"selfloops deleted in ugraph copy constructor");

}


graph::graph(const graph& G)
{ undirected = G.undirected;
  copy_graph(G);
  node_data_map = new graph_map(this,0);
  edge_data_map = new graph_map(this,1);
  adj_iterator = new graph_map(this,0,0);
 }


graph& graph::operator=(const graph& G)
{ if (&G != this)
  { graph::clear();
    undirected = G.undirected;
    copy_graph(G);
```

```
    }
   return *this;
 }


 void graph::join(graph& G)
 { // moves all objects from G to this graph and clears G

   if (G.undirected != undirected)
         error_handler(1,"graph::join(G): cannot merge directed and
 undirected graphs.");

   for(int d=0; d<3; d++) {
      if (G.data_sz[d] != data_sz[d])
         error_handler(1,"graph::join(G): cannot merge graphs with
 different data sizes.");

   }

   node v;
   edge e;
   face f;

   int i = max_n_index;
   forall_nodes(v,G) { v->id = ++i; v->owner = this; }
   max_n_index = i;

   int j = max_e_index;
   forall_edges(e,G) e->id = ++j;
   max_e_index = j;

   int k = max_f_index;
   forall_faces(f,G) f->id = ++k;
   max_f_index = k;

   v_list.conc(G.v_list);
   e_list.conc(G.e_list);
   f_list.conc(G.f_list);

   G.max_n_index = -1;
   G.max_e_index = -1;
   G.max_f_index = -1;
 }




 // subgraph constructors  (do not work for undirected graphs)

 /*
 graph::graph(graph& G, const list<node>& nl, const list<edge>& el)
 { // construct subgraph (nl,el) of graph G

   parent = &G;
   node v,w;
   edge e;

   node* N = new node[G.max_n_index+1];
```

```
  forall(v,nl)
   { if (graph_of(v) != parent)
       error_handler(1,"graph: illegal node in subgraph constructor");
     N[index(v)] = new_node((GenPtr)v);
    }

  forall(e,el)
   { v = source(e);
     w = target(e);
     if ( graph_of(e)!= parent || N[index(v)]==0 || N[index(w)]==0 )
      error_handler(1,"graph: illegal edge in subgraph constructor");
     new_edge(N[index(v)],N[index(w)],(GenPtr)e);
    }

  undirected = G.undirected;

  delete[] N;

 }

graph::graph(graph& G, const list<edge>& el)
{ // construct subgraph of graph G with edge set el

  node  v,w;
  edge  e;
  node* N = new node[G.max_n_index+1];

  forall_nodes(v,G) N[index(v)] = 0;

  parent = &G;

  forall(e,el)
   { v = source(e);
     w = target(e);
     if (N[index(v)] == 0) N[index(v)] = new_node((GenPtr)v);
     if (N[index(w)] == 0) N[index(w)] = new_node((GenPtr)w);
     if ( graph_of(e) != parent )
      error_handler(1,"graph: illegal edge in subgraph constructor");
     new_edge(N[index(v)],N[index(w)],(GenPtr)e);
    }

  undirected = G.undirected;

  delete[] N;

 }

*/


//-----------------------------------------------------------------------
--------
// destruction
//-----------------------------------------------------------------------
--------


void graph::del_all_nodes() { clear(); }

void graph::del_all_edges()
{
```

```
  edge e;

  e = (edge)e_list.head();
  while (e)
  { edge next = (edge)e_list.succ(e);
    dealloc_edge(e);
    e = next;
   }

  e = (edge)h_list.head();
  while (e)
  { edge next = (edge)h_list.succ(e);
    dealloc_edge(e);
    e = next;
   }

  e = (edge)e_free.head();
  while (e)
  { edge next = (edge)e_free.succ(e);
    dealloc_edge(e);
    e = next;
   }

  e_list.clear();
  h_list.clear();
  e_free.clear();

  max_e_index = -1;

  node v;
  forall_nodes(v,*this)
    for(int i=0; i<2; i++)
    { v->first_adj_edge[i] = nil;
      v->last_adj_edge[i] = nil;
      v->adj_length[i] = 0;
     }
}


void graph::del_all_faces()
{
  face f = (face)f_list.head();
  while (f)
  { face next = (face)f_list.succ(f);
    dealloc_face(f);
    f = next;
   }

  f = (face)f_free.head();
  while (f)
  { face next = (face)f_free.succ(f);
    dealloc_face(f);
    f = next;
   }

  f_free.clear();
  f_list.clear();

  if (FaceOf)
  { delete FaceOf;
    FaceOf = 0;
```

```
  }

  max_f_index = -1;
}


void graph::clear()
{
  pre_clear_handler();

  for(int k=0; k<3; k++)
  { graph_map* m;
    forall(m,map_list[k])
      if (m->g_index > 0) m->clear_table();
   }

  del_all_faces();
  del_all_edges();

  node v = (node)v_list.head();
  while (v)
  { node next = (node)v_list.succ(v);
    dealloc_node(v);
    v = next;
   }

  v = (node)v_free.head();
  while (v)
  { node next = (node)v_free.succ(v);
    dealloc_node(v);
    v = next;
   }

  v_list.clear();
  v_free.clear();

  max_n_index = -1;

  post_clear_handler();
}


graph::~graph()
{ clear();
  for(int k=0; k<3; k++)
  { graph_map* m;
    forall(m,map_list[k]) m->g = 0;
   }
  delete adj_iterator;
  delete node_data_map;
  delete edge_data_map;
}

//-----------------------------------------------------------------------
--------
// accessing node and edge lists
//-----------------------------------------------------------------------
--------
```

```
const list<node>& graph::all_nodes() const
{ ((list<node>&)v_list_tmp).clear();
  node v;
  forall_nodes(v,*this)
      ((list<node>&)v_list_tmp).append(v);
  return v_list_tmp;
}


const list<edge>& graph::all_edges() const
{ ((list<edge>&)e_list_tmp).clear();
  edge e;
  forall_edges(e,*this)
      ((list<edge>&)e_list_tmp).append(e);
  return e_list_tmp;
}

const list<face>& graph::all_faces() const
{ ((list<face>&)f_list_tmp).clear();
  face f;
  forall_faces(f,*this)
      ((list<face>&)f_list_tmp).append(f);
  return f_list_tmp;
}


list<edge> graph::out_edges(node v) const
{ list<edge> result;
  edge e;
  forall_out_edges(e,v) result.append(e);
  return result;
}


list<edge> graph::in_edges(node v) const
{ list<edge> result;
  edge e;
  forall_in_edges(e,v) result.append(e);
  return result;
}

list<edge> graph::adj_edges(node v) const
{ list<edge> result;
  edge e;
  forall_adj_edges(e,v) result.append(e);
  return result;
}


list<node> graph::adj_nodes(node v) const
{ list<node> result;
  edge e;
  forall_adj_edges(e,v) result.append(opposite(v,e));
  return result;
}
```

```
//-------------------------------------------------------------------------
--------
// update operations
//-------------------------------------------------------------------------
--------


list<edge> graph::insert_reverse_edges()
{ list<edge> L;
  edge e = first_edge();

  if (e != nil)
  { L.append(new_edge(target(e),source(e),e->data[0]));
    copy_edge_entry(e->data[0]);
    e = succ_edge(e);
   }

  edge stop = last_edge();

  while (e != stop)
  { L.append(new_edge(target(e),source(e),e->data[0]));
    copy_edge_entry(e->data[0]);
    e = succ_edge(e);
   }

  return L;
}



face graph::add_face(GenPtr inf)
{ face f;
  if ( f_free.empty() )
    { f = (face)std_memory.allocate_bytes(face_bytes());
      new (f) face_struct(inf);
      f->owner = this;
      f->id = ++max_f_index;
     }
  else
    { f = (face)f_free.pop();
      f->data[0] = inf;
     }

  f_list.append(f);

  graph_map* m;
  forall(m,map_list[2]) m->re_init_entry(f);

  return f;
}

void graph::dealloc_face(face f)
{ std_memory.deallocate_bytes(f,face_bytes()); }

void graph::del_face(face f)
{ f_list.remove(f);
  f_free.append(f);
  graph_map* m;
  forall(m,map_list[2])
  { int i = m->g_index;
    if (i > 0) m->clear_entry(f->data[i]);
```

```
    }
  }


node graph::add_node(GenPtr inf)
{ node v;
  if ( v_free.empty() )
    { v = (node)std_memory.allocate_bytes(node_bytes());
      new (v) node_struct(inf);
      v->owner = this;
      v->id = ++max_n_index;
      v->succ_link = nil;
     }
  else
    { v = (node)v_free.pop();
      v->data[0] = inf;
     }

  v_list.append(v);

  graph_map* m;
  forall(m,map_list[0]) m->re_init_entry(v);

  return v;
}


void graph::dealloc_node(node v)
{ std_memory.deallocate_bytes(v,node_bytes()); }



node graph::new_node()
{ GenPtr x = 0;
  pre_new_node_handler();
  init_node_entry(x);
  node v = add_node(x);
  post_new_node_handler(v);
  return v;
}


node graph::new_node(GenPtr i)
{ pre_new_node_handler();
  node v = add_node(i);
  post_new_node_handler(v);
  return v;
}


void graph::del_node(node v)
{
  if (v->owner != this)
        error_handler(4,"del_node(v): v is not in G");


  // delete adjacent edges

  edge  e;
  while ((e=v->first_adj_edge[0]) != nil) del_edge(e);
```

```
  if (!undirected)
     while ((e=v->first_adj_edge[1]) != nil) del_edge(e);

  pre_del_node_handler(v);

  if (parent==0) clear_node_entry(v->data[0]);

  v_list.remove(v);
  v_free.append(v);

  graph_map* m;
  forall(m,map_list[0])
  { int i = m->g_index;
    if (i > 0) m->clear_entry(v->data[i]);
   }

  post_del_node_handler();
}


node graph::merge_nodes(node v1, node v2)
{
  if (undirected)
    error_handler(1,"merge_nodes not implemented for undirected
graphs.");


  for(int i=0; i<2; i++)
  {

    if (v1->last_adj_edge[i])
        v1->last_adj_edge[i]->succ_adj_edge[i]  = v2->first_adj_edge[i];
    else
        v1->first_adj_edge[i] = v2->first_adj_edge[i];

    if (v2->first_adj_edge[i])
    {  v2->first_adj_edge[i]->pred_adj_edge[i] = v1->last_adj_edge[i];
       v1->last_adj_edge[i] = v2->last_adj_edge[i];
     }

    v1->adj_length[i] += v2->adj_length[i];

    v2->adj_length[i] = 0;
    v2->first_adj_edge[i] = 0;
    v2->last_adj_edge[i] = 0;
   }

  del_node(v2);
  return v1;
}



edge graph::add_edge(node v, node w, GenPtr inf)
{ edge e;

  if (v->owner != this)
     error_handler(6, "new_edge(v,w): v not in graph");
```

```
  if (w->owner != this)
     error_handler(6, "new_edge(v,w): w not in graph");

  if ( e_free.empty() )
    { e = (edge)std_memory.allocate_bytes(edge_bytes());
      new (e) edge_struct(v,w,inf);
      e->id = ++max_e_index;
     }
  else
    { e = (edge)e_free.pop();
      e->data[0] = inf;
      e->term[0] = v;
      e->term[1] = w;
      e->rev = nil;
      e->succ_adj_edge[0] = nil;
      e->succ_adj_edge[1] = nil;
      e->pred_adj_edge[0] = nil;
      e->pred_adj_edge[1] = nil;
    }

  e_list.append(e);

  graph_map* m;
  forall(m,map_list[1]) m->re_init_entry(e);

  return e;
}


void graph::dealloc_edge(edge e)
{ std_memory.deallocate_bytes(e,edge_bytes()); }



void graph::del_adj_edge(edge e, node v, node w)
{ if (undirected)
    { v->del_adj_edge(e,0,0);
      w->del_adj_edge(e,0,1);
     }
  else
    { v->del_adj_edge(e,0,0);
      w->del_adj_edge(e,1,1);
     }
 }



void graph::ins_adj_edge(edge e, node v, edge e1, node w, edge e2,int
d1,int d2)
{
  // insert edge e
  // after(if d1=0)/before(if d1=1) e1 to adj_list of v
  // after(if d2=0)/before(if d2=1) e2 to in_list (adj_list) of w
  // (most general form of new_edge)

  if ( undirected )
   { if (v == w)
        error_handler(1,"new_edge(v,e1,w,e2): selfloop in undirected
graph.");
     if (e1 && v != source(e1) && v != target(e1))
```

```
        error_handler(1,"new_edge(v,e1,w,e2): v is not adjacent to
e1.");
      if (e2 && w != source(e2) && w != target(e2))
        error_handler(1,"new_edge(v,e1,w,e2): w is not adjacent to
e2.");

      v->insert_adj_edge(e,e1,0,0,d1);
      w->insert_adj_edge(e,e2,0,1,d2);
    }
  else
    { if (e1 && v != source(e1))
        error_handler(1,"new_edge(v,e1,w,e2): v is not source of e1.");
      if (e2 && w != source(e2) && w != target(e2))
        error_handler(1,"new_edge(v,e1,w,e2): w is not target of e2.");

      v->insert_adj_edge(e,e1,0,0,d1);
      w->insert_adj_edge(e,e2,1,1,d2);
     }
}


edge graph::new_edge(node v, edge e1, node w, edge e2, GenPtr i,int
d1,int d2)
{
  // add edge (v,w,i)
  // after(if d1=0)/before(if d1=1) e1 to adj_list of v
  // after(if d2=0)/before(if d2=1) e2 to in_list (adj_list) of w
  // (most general form of new_edge)

  if ( undirected )
   { if (v == w)
        error_handler(1,"new_edge(v,e1,w,e2): selfloop in undirected
graph.");
      if (e1 && v != source(e1) && v != target(e1))
        error_handler(1,"new_edge(v,e1,w,e2): v is not adjacent to
e1.");
      if (e2 && w != source(e2) && w != target(e2))
        error_handler(1,"new_edge(v,e1,w,e2): w is not adjacent to
e2.");
    }
  else
   { if (e1 && v != source(e1))
        error_handler(1,"new_edge(v,e1,w,e2): v is not source of e1.");
      if (e2 && w != source(e2) && w != target(e2))
        error_handler(1,"new_edge(v,e1,w,e2): w is not target of e2.");
     }

  pre_new_edge_handler(v,w);
  edge e = add_edge(v,w,i);
  ins_adj_edge(e,v,e1,w,e2,d1,d2);
  post_new_edge_handler(e);
  return e ;
}

edge graph::new_edge(node v, edge e1, node w, GenPtr i,int d)
{
  // add edge (v,w) after/before e1 to adj_list of v
  // append it to in_list (adj_list) of w

  return new_edge(v,e1,w,nil,i,d,0);
```

```
}

edge graph::new_edge(node v, node w, edge e2, GenPtr i,int d)
{
  // append edge (v,w) to adj_list of v
  // insert it after/before e2 to in_list (adj_list) of w

  return new_edge(v,nil,w,e2,i,d,0);
}

edge graph::new_edge(edge e1, node w, GenPtr i, int dir)
{
  // add edge (source(e1),w) after/before e1 to adj_list of source(e1)
  // append it to in_list (adj_list) of w

  return new_edge(source(e1),e1,w,nil,i,dir,0);
 }

edge graph::new_edge(node v, edge e2, GenPtr i, int dir)
{
  // append edge(v,target(e2))  to adj_list of v
  // insert it after/before e2 to in_list (adj_list) of target(e2)

  return new_edge(v,nil,target(e2),e2,i,0,dir);
 }

edge graph::new_edge(edge e1, edge e2, GenPtr i, int dir1, int dir2)
{
  //add edge (source(e1),target(e2))
  //after(dir=0)/before(dir=1) e1 to adj_list of source(e1)
  //after(dir=1)/before(dir=1) e2 to in_list (adj_list) of target(e2)

  return new_edge(source(e1),e1,target(e2),e2,i,dir1,dir2);
 }


edge graph::new_edge(node v, node w, GenPtr i)
{
  // append (v,w) it to adj_list of v and to in_list (adj_list) of w

  return new_edge(v,nil,w,nil,i,0,0);
 }




node graph::split_edge(edge e, GenPtr node_inf, edge& e1, edge& e2)
{
   // splits e into e1 and e2 by putting new node v on e


  //node v = source(e);
  node w = target(e);
  node u = add_node(node_inf);

  e1 = e;
  e2 = add_edge(u,w,e->data[0]);

  copy_edge_entry(e2->data[0]);
```

```
  if (undirected)
    { u->append_adj_edge(e2,0,0);
      w->insert_adj_edge(e2,e,0,1,0);
      w->del_adj_edge(e,0,1);
      e->term[1] = u;
      u->append_adj_edge(e,0,1);
     }
  else
    { u->append_adj_edge(e2,0,0);
      w->insert_adj_edge(e2,e,1,1,0);
      w->del_adj_edge(e,1,1);
      e->term[1] = u;
      u->append_adj_edge(e,1,1);
     }

 return u;
}



void graph::del_edge(edge e)
{ node v = source(e);
  node w = target(e);

  if (v->owner != this) error_handler(10,"del_edge(e): e is not in G");

  pre_del_edge_handler(e);

  if (is_hidden(e)) restore_edge(e);

  if (e->rev) e->rev->rev = nil;

  del_adj_edge(e,v,w);

  if (parent == 0) clear_edge_entry(e->data[0]);

  e_list.remove(e);
  e_free.append(e);

  graph_map* m;
  forall(m,map_list[1])
  { int i = m->g_index;
    if (i > 0) m->clear_entry(e->data[i]);
   }

  post_del_edge_handler(v,w);
}


void graph::hide_edge(edge e)
{
  if (is_hidden(e))
    error_handler(1,"graph::hide_edge: edge is already hidden.");

  pre_hide_edge_handler(e);


  node v = source(e);
  node w = target(e);
```

```
  del_adj_edge(e,v,w);

  e_list.remove(e);
  h_list.append(e);

  e->id |= 0x80000000;

  post_hide_edge_handler(e);
 }


void graph::restore_edge(edge e)
{
  if (!is_hidden(e))
    error_handler(1,"graph::restore_edge: edge is not hidden.");

  pre_restore_edge_handler(e);

  node v = source(e);
  node w = target(e);

  h_list.remove(e);
  e_list.append(e);

  if (undirected)
    { v->append_adj_edge(e,0,0);
      w->append_adj_edge(e,0,1);
     }
  else
    { v->append_adj_edge(e,0,0);
      w->append_adj_edge(e,1,1);
     }

  e->id = index(e);

  post_restore_edge_handler(e);
}


void graph::restore_all_edges()
{ edge e = (edge)h_list.head();
  while (e)
  { edge succ = (edge)h_list.succ(e);
    restore_edge(e);
    e = succ;
  }
 }


void graph::move_edge(edge e,edge e1,edge e2,int d1,int d2)
{ if (is_hidden(e))
        error_handler(1,"graph::move_edge:  cannot move hidden edge.");
  node v0 = source(e);
  node w0 = target(e);
  node v = source(e1);
  node w = target(e2);
  pre_move_edge_handler(e,v,w);
  del_adj_edge(e,source(e),target(e));
  e->term[0] = v;
```

```
  e->term[1] = w;
  ins_adj_edge(e,v,e1,w,e2,d1,d2);
  post_move_edge_handler(e,v0,w0);
 }

void graph::move_edge(edge e,edge e1,node w,int dir)
{ if (is_hidden(e))
       error_handler(1,"graph::move_edge:  cannot move hidden edge.");
  node v0 = source(e);
  node w0 = target(e);
  node v = source(e1);
  pre_move_edge_handler(e,v,w);
  del_adj_edge(e,source(e),target(e));
  e->term[0] = v;
  e->term[1] = w;
  ins_adj_edge(e,source(e1),e1,w,nil,dir,0);
  post_move_edge_handler(e,v0,w0);
}

void graph::move_edge(edge e, node v, node w)
{ if (is_hidden(e))
       error_handler(1,"graph::move_edge:  cannot move hidden edge.");
  node v0 = source(e);
  node w0 = target(e);
  pre_move_edge_handler(e,v,w);
  del_adj_edge(e,source(e),target(e));
  e->term[0] = v;
  e->term[1] = w;
  ins_adj_edge(e,v,nil,w,nil,0,0);
  post_move_edge_handler(e,v0,w0);
 }


edge graph::rev_edge(edge e)
{ if (is_hidden(e))
       error_handler(1,"graph::move_edge:  cannot move hidden edge.");
  node v = source(e);
  node w = target(e);

  pre_move_edge_handler(e,w,v);

  if (is_hidden(e)) // e hidden
  { e->term[0] = w;
    e->term[1] = v;
    return e;
   }

  if (undirected)
  { edge s = e->succ_adj_edge[0];
    edge p = e->pred_adj_edge[0];
    e->succ_adj_edge[0] = e->succ_adj_edge[1];
    e->pred_adj_edge[0] = e->pred_adj_edge[1];
    e->succ_adj_edge[1] = s;
    e->pred_adj_edge[1] = p;
    e->term[0] = w;
    e->term[1] = v;
   }
  else
  { del_adj_edge(e,v,w);
    e->term[0] = w;
    e->term[1] = v;
```

```
     ins_adj_edge(e,w,nil,v,nil,0,0);
    }

   post_move_edge_handler(e,v,w);

   return e;
}


void graph::rev_all_edges()
{ if (!undirected)
   { list<edge> L = all_edges();
     edge e;
     forall(e,L) rev_edge(e);
    }
}


void graph::del_nodes(const list<node>& L)
{ node v;
  forall(v,L) del_node(v);
 }

void graph::del_edges(const list<edge>& L)
{ edge e;
  forall(e,L) del_edge(e);
 }

void graph::make_undirected()
{
  if (undirected) return;

  list<edge> loops;
  edge e;

  forall_edges(e,*this)
    if (source(e) == target(e))  loops.append(e);

  if ( ! loops.empty() )
      error_handler(0,"selfloops deleted in ugraph constructor");

  forall(e,loops) del_edge(e);


  /* adj_list(v) = out_list(v) + in_list(v) forall nodes v  */

  node v;
  forall_nodes(v,*this)
  {
    // append in_list to adj_list

    if (v->first_adj_edge[1] == nil) continue;


    if (v->first_adj_edge[0] == nil) // move in_list to adj_list
      { v->first_adj_edge[0] = v->first_adj_edge[1];
        v->last_adj_edge[0]  = v->last_adj_edge[1];
        v->adj_length[0]     = v->adj_length[1];
       }
    else // both lists are non-empty
      { v->last_adj_edge[0]->succ_adj_edge[0] = v->first_adj_edge[1];
```

```
        v->first_adj_edge[1]->pred_adj_edge[1] = v->last_adj_edge[0];
        v->last_adj_edge[0] = v->last_adj_edge[1];
        v->adj_length[0] += v->adj_length[1];
       }

    v->first_adj_edge[1] = nil;
    v->last_adj_edge[1] = nil;
    v->adj_length[1] = 0;

   }

  undirected = true;
}


void graph::make_directed()
{
  if (!undirected) return;

  // for every node v delete entering edges from adj_list(v)
  // and put them back into in_list(v)

  node v;
  forall_nodes(v,*this)
  { edge e = v->first_adj_edge[0];
    while (e)
      if (v == target(e))
         { edge e1 = e->succ_adj_edge[1];
           v->del_adj_edge(e,0,1);
           v->append_adj_edge(e,1,1);
           e = e1;
          }
      else
         e = e->succ_adj_edge[0];
   }

  undirected = false;

}



void init_node_data(const graph& G,int i, GenPtr x)
{ node v;
  forall_nodes(v,G) v->data[i] = x;
 }



int graph::register_map(graph_map* M)
{ int k = M->kind;

  M->g_loc = map_list[k].append(M);

#if defined(LEDA_GRAPH_DATA)
  if  (free_data[k].empty())
     error_handler(1,
        string("graph::register_map: all data (%d) slots
used",data_sz[k]));
#endif
```

```
  return (free_data[k].empty()) ? -1 : free_data[k].pop();
}


void graph::unregister_map(graph_map* M)
{ int k = M->kind;
  map_list[k].del_item(M->g_loc);
  if (M->g_index > 0) free_data[k].push(M->g_index);
}



node graph::choose_node() const
{ int n = number_of_nodes();
  if (n == 0) return nil;
  int r = rand_int(0,n-1);
  node v = first_node();
  while (r--) v = succ_node(v);
  return v;
}


edge graph::choose_edge() const
{ int m = number_of_edges();
  if (m == 0) return nil;
  int r = rand_int(0,m-1);
  edge e = first_edge();
  while (r--) e = succ_edge(e);
  return e;
}


face graph::choose_face() const
{ int l = number_of_faces();
  if (l == 0) return nil;
  int r = rand_int(0,l-1);
  face f = first_face();
  while (r--) f = succ_face(f);
  return f;
}


//-----------------------------------------------------------------------
--------
// old iterator stuff
//-----------------------------------------------------------------------
--------

void graph::init_adj_iterator(node v) const
{ adj_iterator->map_access(v) = nil; }

bool  graph::current_adj_edge(edge& e, node v) const
{ return (e = (edge)adj_iterator->map_access(v)) != nil;}

bool  graph::next_adj_edge(edge& e, node v) const
{ edge cur = (edge)adj_iterator->map_access(v);
  e = (cur) ? adj_succ(cur) : first_adj_edge(v);
  adj_iterator->map_access(v) = e;
  return  (e) ? true : false;
```

```
 }

bool graph::next_adj_node(node& w, node v)  const
{ edge e;
  if (next_adj_edge(e,v))
  { w = opposite(v,e);
    return true;
   }
  else return false;
 }

bool graph::current_adj_node(node& w, node v)  const
{ edge e;
  if (current_adj_edge(e,v))
  { w = opposite(v,e);
    w = target(e);
    return true;
   }
  else return false;
}


void graph::reset()  const   // reset all iterators
{ adj_iterator->init(this,max_n_index+1,0);
  node v;
  forall_nodes(v,*this) adj_iterator->map_access(v) = nil;
}
```

```
/*******************************************************************************
*******
+
+  LEDA 3.5.1
+
+  _planar_map.c
+
+  This file is part of the LEDA research version (LEDA-R) that can be
+  used free of charge in academic research and teaching. Any commercial
+  use of this software requires a license which is distributed by the
+  LEDA Software GmbH, Postfach 151101, 66041 Saarbruecken, FRG
+  (fax +49 681 31104).
+
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+  Im Stadtwald, 66123 Saarbruecken, Germany
+  All rights reserved.
+
*******************************************************************************
*******/
#include <LEDA/planar_map.h>


void planar_map::init_face_entries() const
{ face f;
  forall_faces(f,*this) init_face_entry(f->data[0]);
 }

void planar_map::copy_face_entries() const
{ face f;
  forall_faces(f,*this) copy_face_entry(f->data[0]);
 }

void planar_map::clear_face_entries() const
{ face f;
  forall_faces(f,*this) clear_face_entry(f->data[0]);
 }



node planar_map::new_node(const list<edge>& el)
{
  if (el.length() < 2)
      error_handler(1,"planar_map::new_node(el,i):  el.length() < 2.");

  list_item it = el.first();

  edge e0 = el[it];

  it = el.succ(it);

  face f = adj_face(e0);

  edge e;
  forall(e,el)
  { if (adj_face(e) != f)
      error_handler(1,"planar_map::new_node: edges bound different
faces.");
   }

  e = el[it];
```

```
  it = el.succ(it);

  GenPtr face_inf = f->data[0];
  copy_face_entry(face_inf);

  edge x = new_edge(e0,e);
  face fx = adj_face(reversal(x));
  clear_face_entry(fx->data[0]);
  fx->data[0] = face_inf;

  edge e1 = split_edge(x);

  while(it)
  { copy_face_entry(face_inf);
    e1 = new_edge(e1,el[it]);
    face fx = adj_face(reversal(e1));
    clear_face_entry(fx->data[0]);
    fx->data[0] = face_inf;
    it = el.succ(it);
   }

  return source(e1);
}
```

```
/***********************************************************************
********
+
+  LEDA 3.5.1
+
+  _pq_tree.c
+
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+
************************************************************************
*******/
//----------------------------------------------------------------------
--
// PQ_TREES
//
// R. Hesse, E. Kalliwoda, D. Ambras (1996/97)
//
//----------------------------------------------------------------------
--

#include <LEDA/pq_tree.h>
#include <LEDA/queue.h>

const int
  D_NODE_INVALID=0,
  D_NODE_PNODE   =1,
  D_NODE_QNODE   =2,
  D_NODE_LEAF    =3,
  D_NODE_DIR     =4,

  D_NODE_UNMARKED  =6,
  D_NODE_UNBLOCKED =7,
  D_NODE_BLOCKED   =8,
  D_NODE_QUEUED    =9,

  D_NODE_EMPTY     =10,
  D_NODE_FULL      =11,
  D_NODE_PARTIAL   =12,
  D_NODE_DOUBLE_PARTIAL  =13;


pq_node_struct::pq_node_struct()
{
  leaf_index  = 0;
  child_count = 0;

  parent          = NULL;
  link_one_side   = NULL;
  link_other_side = NULL;
  right_most      = NULL;
  left_most       = NULL;

  type          = D_NODE_PNODE;
```

```
  parent_type    = D_NODE_QNODE;

  node_reset();
}


void pq_node_struct::node_reset()
{
  mark   = D_NODE_UNMARKED;
  status = D_NODE_EMPTY;          // vielleicht auf FULL umstellen ***

  pert_leaf_count  = 0;
  pert_child_count = 0;
  full_child_count = 0;

  part_child1 = NULL;
  part_child2 = NULL;
}



pq_tree::pq_tree(int lsize)
{
  successful              = true;
  too_many_part           = false;
  leaves_size             = lsize;
  blocked_chain_count     = 0;
  blocked_nodes_count     = 0;

  root                    = NULL;
  pseudo_root             = new pq_node_struct;
  pseudo_root->leaf_index = 2;

  if (lsize > 0)  leaves_init(lsize+1);
    else  leaves = NULL;
}


//----------------------------------------------------------------------
--
// TEMPLATES
//----------------------------------------------------------------------
--


void pq_tree::fix_part_child_direction(pq_node x, bool part_child2_too)
{
 pq_node       k;
 pq_node       child1= x->part_child1;
 pq_node       child2= x->part_child2;

 if (child1->left_most->status == D_NODE_FULL)
 { k= child1->left_most;
   child1->left_most  = child1->right_most;
   child1->right_most = k;
 }

 if (part_child2_too)
   if (child2->right_most->status == D_NODE_FULL)
```

```
    {   k= child2->left_most;
        child2->left_most  = child2->right_most;
        child2->right_most = k;
    }
}



inline void pq_tree::append_as_right_child(pq_node parent, pq_node
child)
{
  pq_node  l= parent->right_most;

  if (l->link_one_side)
      l->link_other_side = child;
  else
      l->link_one_side = child;

  child->link_one_side  = l;
  child->link_other_side= NULL;

  parent->right_most = child;
}



pq_node pq_tree::hang_down_full_children(pq_node x, pq_node z)
{
  int        x_full_child_count= x->full_child_count;
  pq_node  y;


    if (x_full_child_count == 0)  return NULL;

    if (x_full_child_count == 1)
    {
       y= remove_from_siblings(x, x->right_most);
       y->parent = z;
       y->parent_type = z->type;
       append_as_right_child(z, y);

       z->child_count++;
       z->full_child_count++;
       z->pert_leaf_count = x->pert_leaf_count;
       x->full_child_count = 0;
       x->child_count--;

       return y;
    }


  pq_node  l;

    y = new pq_node_struct;
    y->parent = z;
    y->parent_type = z->type;
    y->status = D_NODE_FULL;
    processed.push(y);
```

```
    y->left_most = x->right_most;
    y->right_most= x->right_most;

    y->left_most->parent = y;
    l = NULL;
    for(int i = 1; i < x_full_child_count; i++)
    { go_to_sibling(y->left_most, l);
      y->left_most->parent = y;
    }



    pq_node  k, sibling;
    pq_node  y_left= y->left_most;

    if (y_left->link_one_side == l)
    {   k= y_left->link_other_side;
          y_left->link_other_side = NULL;
    }
    else
    {   k= y_left->link_one_side;
          y_left->link_one_side = NULL;
    }

    if (x != z)
    { x->right_most = k;
      append_as_right_child(z, y);
      sibling= NULL;
    }
    else
    { x->right_most = y;
      y->link_one_side = k;
      sibling= y;
    }

    if (k->link_one_side == y_left)
      k->link_one_side = sibling;
    else
      k->link_other_side = sibling;



    y->child_count      = y->full_child_count = x->full_child_count;

    x->full_child_count = 0;
    x->child_count     -= y->child_count;

    y->pert_leaf_count  = x->pert_leaf_count;
    if (x->part_child1)
      y->pert_leaf_count -= x->part_child1->pert_leaf_count;
    if (x->part_child2)
      y->pert_leaf_count -= x->part_child2->pert_leaf_count;

    z->child_count++;
    z->full_child_count++;
    z->pert_leaf_count += y->pert_leaf_count;

  return y;
}
```

```
pq_node pq_tree::remove_from_siblings(pq_node parent, pq_node child)
{
  if (child->link_one_side)
    if (child->link_one_side->link_one_side == child)
        child->link_one_side->link_one_side =  child->link_other_side;
    else
        child->link_one_side->link_other_side= child->link_other_side;

  if (child->link_other_side)
    if (child->link_other_side->link_one_side == child)
        child->link_other_side->link_one_side =  child->link_one_side;
    else
        child->link_other_side->link_other_side= child->link_one_side;


  if (parent->right_most == child)
    parent->right_most = child->link_one_side ?
                         child->link_one_side : child->link_other_side;

  if (parent->left_most == child)
    parent->left_most = child->link_one_side ?
                        child->link_one_side : child->link_other_side;


  if (parent->part_child1 == child)
  { parent->part_child1= parent->part_child2;
    parent->part_child2= NULL;
  }
  if (parent->part_child2 == child)  parent->part_child2= NULL;

 return child;
}


void pq_tree::replace_in_siblings(pq_node x, pq_node z)
{
  z->parent = x->parent;
  z->parent_type = x->parent_type;

  z->link_one_side = x->link_one_side;
  z->link_other_side = x->link_other_side;

  if (z->link_one_side)
    if (z->link_one_side->link_one_side == x)
        z->link_one_side->link_one_side = z;
    else
        z->link_one_side->link_other_side = z;

  if (z->link_other_side)
    if (z->link_other_side->link_one_side == x)
        z->link_other_side->link_one_side = z;
    else
        z->link_other_side->link_other_side = z;

  if (z->parent)
  { if (z->parent->right_most == x)  z->parent->right_most = z;
```

```
    if (z->parent->left_most  == x)  z->parent->left_most  = z;
  }
}



bool pq_tree::set_as_part_child(pq_node x)
{
   x->status = D_NODE_PARTIAL;

   if (x->parent->part_child1)
   { if (x->parent->part_child2)
     { too_many_part = true;
       return false;
     }
     else  x->parent->part_child2 = x;
   }
   else  x->parent->part_child1 = x;

 return true;
}



inline void pq_tree::append_as_left_child(pq_node parent, pq_node child)
{
  pq_node  l= parent->left_most;

  child->parent = parent;
  child->parent_type = D_NODE_QNODE;              // ist immer so

  if (l->link_one_side)
      l->link_other_side = child;
  else
      l->link_one_side = child;

  child->link_one_side  = NULL;
  child->link_other_side= l;

  parent->left_most = child;
}


void pq_tree::delete_part_node_parent(pq_node x)
{
  replace_in_siblings(x, x->part_child1);

  if (x == root)
  { root= x->part_child1;
    root->parent = NULL;
    root->link_one_side = NULL;
    root->link_other_side = NULL;
  }

  delete x;
}
```

```
bool pq_tree::template_PQL1(pq_node x, bool is_pseudo_root)
{

#ifdef _DEBUG_PQ_TREE
  if (x->type == D_NODE_PNODE)  cout << "P1";
    else
    if (x->type == D_NODE_QNODE)  cout << "Q1";
      else  cout << "L1";
#endif


  if (x->type == D_NODE_QNODE)
  { pq_node  k;
    pq_node  last_k= NULL;

    if (x->part_child1) return false;
    if (x == pseudo_root) return true;

    k = x->right_most;
    while (k)
    { if (k->type != D_NODE_DIR && k->status == D_NODE_EMPTY)
        return false;
      go_to_sibling(k, last_k);
    }
  }
  else
    if (x->full_child_count != x->child_count) return false;


  if (x->parent_type == D_NODE_PNODE &&  x->parent &&
      x->parent->right_most != x )
  {
    remove_from_siblings(x->parent, x);
    append_as_right_child(x->parent, x);
  }

  x->status = D_NODE_FULL;
  processed.push(x);

  if (is_pseudo_root)
  {
    pseudo_root->left_most  = x;
    pseudo_root->right_most = x;
  }
  else
    if (x->parent)  x->parent->full_child_count++;

  return true;
}



bool pq_tree::template_P3(pq_node x, bool is_pseudo_root)
{
  pq_node    y, z;
```

```
#ifdef _DEBUG_PQ_TREE
  if (is_pseudo_root)  cout << "P2";
    else  cout << "P3";
  assert(x != root);
  cons_pq_tree(root,"b","P2/3");
#endif

  if (x->part_child1)  return false;

  if (x->full_child_count > 1)
    y= hang_down_full_children(x, x);
  else
    y= x->right_most;

  if (is_pseudo_root)
  {
    pseudo_root->left_most  = y;
    pseudo_root->right_most = y;
    x->node_reset();

    return true;
  }



  if (x->child_count > 2)
  {
    z = new pq_node_struct;
    z->mark = D_NODE_UNBLOCKED;

                    //for correct blocked chain handling in reduce():

    if (x == pseudo_root->left_most)  pseudo_root->left_most = z;
    if (x == pseudo_root->right_most) pseudo_root->right_most = z;

    replace_in_siblings(x, z);

    x->right_most = y->link_one_side ?
                    y->link_one_side : y->link_other_side;

    if (x->right_most->link_one_side == y)
       x->right_most->link_one_side = NULL;
    else
       x->right_most->link_other_side = NULL;

    x->child_count--;
    x->node_reset();



    x->parent = y->parent = z;
    z->left_most = x;
    z->right_most = y;

    x->link_one_side  = NULL;
    x->link_other_side= y;

    y->link_one_side  = NULL;
    y->link_other_side= x;
```

```
    z->pert_leaf_count  = x->pert_leaf_count;
    z->full_child_count = 1;
    z->child_count = 2;
  }
  else  z = x;

  z->type = D_NODE_QNODE;
  z->left_most->parent_type = D_NODE_QNODE;
  z->right_most->parent_type= D_NODE_QNODE;

 return set_as_part_child(z);
}




bool pq_tree::template_P5(pq_node x, bool is_pseudo_root)
{
  pq_node y, k, z;

#ifdef _DEBUG_PQ_TREE
  if (is_pseudo_root)  cout << "P4";
    else  cout << "P5";
  assert(x != root);
  cons_pq_tree(root,"b","P4/5");
#endif


  if (x->part_child2 || too_many_part )  return false;

// if (!x->part_child1 || x->part_child2 || too_many_part )
//    return false;
// "|| too_many_part" muss bleiben, x->part_child1 darf nicht  !?

  fix_part_child_direction(x);

  z = x->part_child1;

  y= hang_down_full_children(x, z);      // Teste, ob es volle Kinder
gibt ? ***
                                         // ( sonst y= NULL )
  if (is_pseudo_root)                    // it's _P4
  {
    pseudo_root->right_most = y;

         // suche letztes volles Kind:

    k = y->link_one_side ?
         y->link_one_side : y->link_other_side;

    while (k->status == D_NODE_FULL || k->type == D_NODE_DIR)
      go_to_sibling(k, y);

    pseudo_root->left_most = y;          // y= letztes volles Kind

    z->node_reset();

    if (x->child_count == 1)
```

```
      delete_part_node_parent(x);
    else
      x->node_reset();

    return true;
  }



  if (x->child_count > 2)
  {
    z->pert_leaf_count = x->pert_leaf_count;
    x->child_count--;
    x->pert_leaf_count = 0;

    x->part_child1 = NULL;
    remove_from_siblings(x, z);
    replace_in_siblings(x, z);
    set_as_part_child(z);
    append_as_left_child(z, x);

    x->node_reset();
  }



  else
  {
      if (x->child_count == 2)
      {
        y = (x->right_most == z) ?
             x->left_most : x->right_most;
        append_as_left_child(z, y);
      }


      // for correct blocked chain handling in reduce():

      z->mark = D_NODE_UNBLOCKED;
      if (x == pseudo_root->left_most)  pseudo_root->left_most = z;
      if (x == pseudo_root->right_most) pseudo_root->right_most = z;

      replace_in_siblings(x, z);
      set_as_part_child(z);

      delete x;
  }

  return !too_many_part;
}



bool pq_tree::template_P6(pq_node x)
{

  #ifdef _DEBUG_PQ_TREE
    cout << "P6";
  #endif
```

```
pq_node k, l;

  if (!x->part_child2 || too_many_part)  return false;

  fix_part_child_direction(x, true);
  hang_down_full_children(x, x->part_child1);


  l = x->part_child1->right_most;
  k = l->link_one_side ?
      l->link_one_side : l->link_other_side;

  while (k->status == D_NODE_FULL || k->type == D_NODE_DIR)
    go_to_sibling(k, l);
  pseudo_root->left_most = l;          // linkestes volles Kind von x-
>part1
  l->parent = x->part_child1;


  l = x->part_child2->left_most;
  k = l->link_one_side ?
      l->link_one_side : l->link_other_side;

  while (k->status == D_NODE_FULL || k->type == D_NODE_DIR)
    go_to_sibling(k, l);
  pseudo_root->right_most = l;         // rechtestes volles Kind von x-
>part2


  k= x->part_child1;
  l= remove_from_siblings(x, x->part_child2);
  x->child_count--;

  if (k->right_most->link_one_side)
     k->right_most->link_other_side = l->left_most;
  else
     k->right_most->link_one_side = l->left_most;

  if (l->left_most->link_one_side)
     l->left_most->link_other_side = k->right_most;
  else
     l->left_most->link_one_side = k->right_most;

  k->right_most = l->right_most;
  k->right_most->parent= k;


  delete l;

  x->part_child1->node_reset();

  if (x->child_count == 1)
    delete_part_node_parent(x);
  else
    x->node_reset();

  return true;
}
```

```
bool pq_tree::template_Q2(pq_node x)
{                  // template for a Q-node with empties and/or 1 partial
child


#ifdef _DEBUG_PQ_TREE
cout << "Q2" << endl;
if (pseudo_root->leaf_index > 1)  show("in Q2",x);
//show("in Q2",x);
//show("in Q2",root);
#endif

   if (x->part_child2)  return false;

//  if (!x->part_child1 || x->part_child2 || too_many_part)     // darf
nicht !
//     return false;


  pq_node k;                        // to run through the children
  pq_node l;                        // dito
  pq_node l1,l2;                    // dito
  pq_node m,n;                      // dito, but see text
  pq_node p1=NULL;                  // the part_child
  pq_node d1;                       // the side the full's will be turned
to ...
  pq_node d2;                       // and the other side
  pq_node aux_leftm=NULL;
  pq_node aux_rightm=NULL;          // dummies for pseudo_root->end_most's

  bool    full_found=false;         // turn the full's to the outside
  bool    a,b,c,d;                  // for testing of blocked chain


  if (p1 = x->part_child1)
  {
    l1 = l2 = x->part_child1;

    m = p1->link_one_side;
    skip_dir(m,l1);

    n = p1->link_other_side;
    skip_dir(n,l2);

   if (x->full_child_count)
   {
    a = m ? m->status == D_NODE_FULL : 0;
    b = n ? n->status == D_NODE_FULL : 0;

    if (!(a ^ b))  return false;   // xor; (both (full)) or (both (NULL
or empty))

    if (x->full_child_count == 1)
    {
```

```
      if (a)
      { d1 = p1->link_one_side;
        d2 = p1->link_other_side;
        k = m;
        l = l1;
      }
      else
      { d2 = p1->link_one_side;
        d1 = p1->link_other_side;
        k = n;
        l = l2;
      }

      go_to_sibling(k, l);

      skip_dir(k, l);
      aux_leftm = l;

// in case of a blocked chain the end_most's of pseudo_root are already
used
// and valid
// next reduce round Q2 will match pseudo_root as the father of the
blocked chain

       full_found = true;

      }
    else
      {
         if (a)
            { k = m; l = l1; }
         else
            { k = n; l = l2; }

         for(int i = 2; i <= x->full_child_count; i++)
         { go_to_sibling(k, l);
           skip_dir(k,l);
           if ( !k || k->status != D_NODE_FULL )  return false;

          //there is an empty between the full's
          //or not all full's are at one side
         }

         full_found = true;
         go_to_sibling(k, l);

         skip_dir(k,l);
         aux_leftm = l;

         if (a)
           { d1 = p1->link_one_side; d2 = p1->link_other_side; }
         else
           { d2 = p1->link_one_side; d1 = p1->link_other_side; }

       }

   }                            //if (x->full_child_count)
  else
   {                            //... no full's, only a part_child

     if (pseudo_root->status == D_NODE_FULL)
```

```
      { // ROOT(T,S) is reached

        d1 = p1->link_one_side;
        d2 = p1->link_other_side;

        if (d1->type == D_NODE_DIR)
        { l = p1;
          k = d1;
          skip_dir(k,l);
          aux_leftm = l;
         }
        else
          if (p1->right_most->status == D_NODE_FULL)
             aux_leftm = p1->right_most;
          else
             aux_leftm = p1->left_most;
       }
      else
      { if (m && n)  return false;        //-part_child is between
empties

        d1 = NULL;                        //-part_child's full endmost
will be
        d2 = m ? p1->link_one_side : p1->link_other_side;
                                   //turned outside and becomes an
end_most
       }
   }

  } //end of "if (p1 = x->part_child1)"
  else
  { // there's no part_child

   if (x->left_most->status == D_NODE_FULL)
     l = x->left_most;
   else
     { l = x->right_most;
       if ( l->status != D_NODE_FULL)  return false;
      }

//   if ( pseudo_root->type != D_NODE_QNODE || x == pseudo_root)
//      aux_rightm = aux_leftm = l;
        aux_rightm = aux_leftm = l;

   if (x->full_child_count > 1)
   {
     k = l->link_one_side ? l->link_one_side : l->link_other_side;
     skip_dir(k,l);

     if (k->status == D_NODE_FULL)
     { for(int i = 2; i <= x->full_child_count; i++)
       { skip_dir(k,l);
         if ( k->status != D_NODE_FULL)  return false;
         go_to_sibling(k, l);
       }
//       if ( pseudo_root->type != D_NODE_QNODE || x == pseudo_root )
//       if ( pseudo_root->status == D_NODE_FULL)
//       {
         skip_dir(k,l);
         aux_leftm = l;
//        }
```

```
    }
   else return false;    // empties are intermingled with full's
 }
} //else from "if (p1 = x->part_child1)"
                         //no empty's and no part_child between full's
                         //template applicable, now the replacement:
if (p1)
{
 if (p1->right_most->status == D_NODE_FULL)
   { m = p1->right_most; n = p1->left_most; }
 else
   { m = p1->left_most, n = p1->right_most; }

 if (m->link_one_side)
    m->link_other_side = d1;
 else
    m->link_one_side = d1;

 if (d1)
    if (d1->link_one_side == p1)
       d1->link_one_side = m;
    else
       d1->link_other_side = m;

 if (n->link_one_side)
    n->link_other_side = d2;
 else
    n->link_one_side = d2;

 if (d2)
    if (d2->link_one_side == p1)
       d2->link_one_side = n;
    else
       d2->link_other_side = n;

 if (p1 == x->left_most)
 { x->left_most = full_found ? n : m;
   x->left_most->parent = x;
  }

 if (p1 == x->right_most)
 { x->right_most = full_found ? n : m;
   x->right_most->parent = x;
  }

 x->part_child1 = NULL;

 //reversed (if necessary) and chained

 x->full_child_count += p1->full_child_count;
 delete p1;

 l = d1;
 k = m;

 while (k && k->status == D_NODE_FULL)
 { k->parent = x;
   go_to_sibling(k, l);
   skip_dir(k,l);
 }
```

```
     aux_rightm = 1;

    }

    if (aux_leftm && aux_rightm)
    { c = aux_leftm->link_one_side && aux_leftm->link_other_side;
      d = aux_rightm->link_one_side && aux_rightm->link_other_side;
      if (c && d)  x->status = D_NODE_DOUBLE_PARTIAL;
     }


    if (pseudo_root->status == D_NODE_FULL || x == pseudo_root){
      pseudo_root->left_most = aux_leftm;
      pseudo_root->right_most = aux_rightm;
    }
    else
    if (x->status == D_NODE_DOUBLE_PARTIAL)  return false;


    if (x != pseudo_root)
    { // father pointer of x is valid, that means != NULL
     if (pseudo_root->status == D_NODE_FULL) // ROOT(T,S) reached
         x->node_reset();
     else
       { x->status = D_NODE_PARTIAL;
         if (x->parent->part_child1)
           { if (x->parent->part_child2)
               { too_many_part = true;
                 return false;
                }
             else
                x->parent->part_child2 = x;
            }
         else
            x->parent->part_child1 = x;
                    //x becomes one of the x->parent->part_children
        }
     }

 return true;

 }




bool pq_tree::template_Q3(pq_node x)
{                 // template for a Q-node with exactly 2 partial
children


#ifdef _DEBUG_PQ_TREE
cout << "Q3";
#endif

  if ( pseudo_root->status != D_NODE_FULL ||
       too_many_part ||
       !x->part_child2 ) return false;
```

```
  pq_node  k;       //to run through the children
  pq_node  l;       //dito
  pq_node  p1;      //a part_child ...
  pq_node  d1;      //... and its neighbour in direction to the full's
  pq_node  p2;      //dito
  pq_node  d2;      //dito
  pq_node  mm,m;    //to run through the children
  pq_node  nn,n;    //dito
  pq_node  l1,l2;   //dito

  unsigned char   cc;     //for a check

  bool a,b;


   l1 = l2 = p1 = x->part_child1;
   m = p1->link_one_side;
   skip_dir(m,l1);

   n = p1->link_other_side;
   skip_dir(n,l2);

   l1 = l2 = p2 = x->part_child2;
   mm = p2->link_one_side;
   skip_dir(mm,l1);
   nn = p2->link_other_side;
   skip_dir(nn,l2);

   if (x->full_child_count)
   { // x has full children

    cc = m ? (m->status == D_NODE_PARTIAL ? 1 :
             (m->status == D_NODE_FULL ? 2 : 0)) : 0;
    cc += n ? (n->status == D_NODE_PARTIAL ? 1 :
              (n->status == D_NODE_FULL ? 2 : 0)) : 0;
    if (cc != 2)  return false;           // OH GOTT !! ***

    d1 = (m && m->status == D_NODE_FULL) ?  p1->link_one_side : p1-
>link_other_side;

    cc = mm ? (mm->status == D_NODE_PARTIAL ? 1 : (mm->status ==
D_NODE_FULL ? 2 : 0)) : 0;
    cc += nn ? (nn->status == D_NODE_PARTIAL ? 1 : (nn->status ==
D_NODE_FULL ? 2 : 0)) : 0;
    if (cc != 2)  return false;           // ***

    d2 = (mm && mm->status == D_NODE_FULL) ? p2->link_one_side : p2-
>link_other_side;

    /*
    explanation:
    check values for
    NULL empty part full
     0     0     1    2

    One sibling is "NULL" or "empty" and the other is "full" is a
necessary
    condition here for a valid Q3 situation (the rest of the test
follows).
```

```
    */

    if (x->full_child_count > 1)
    {
      if (mm && mm->status == D_NODE_FULL)
         { d2 = p2->link_one_side;  k = mm;  l = l1;}
     else
         { d2 = p2->link_other_side;  k = nn;  l = l2;}

     for(int i = 2; i <= x->full_child_count; i++)
     { go_to_sibling(k, l);
       skip_dir(k,l);

       if (!k || k->status != D_NODE_FULL)  return false;
         // because there is an empty or an part_child between the
full's
     }

     go_to_sibling(k, l);
     skip_dir(k,l);

     if (!k || k->status != D_NODE_PARTIAL)  return false;
    }
   }
   else
    { // x has no full child

      a = m ? m->status == D_NODE_PARTIAL : 0;
      b = n ? n->status == D_NODE_PARTIAL : 0;
      d1 = a ? p1->link_one_side : p1->link_other_side;
      if (!(a ^ b))  return false;

      a = mm ? mm->status == D_NODE_PARTIAL : 0;
      b = nn ? nn->status == D_NODE_PARTIAL : 0;
      d2 = a ? p2->link_one_side : p2->link_other_side;
      if (!(a ^ b))  return false;
    }

  //no empties and no part_child between full's
  //template is applicable, now the replacement:

  pq_node m1,m2;  //the full end_most of a part_child
  pq_node n1,n2;  //the empty end_most of a part_child
  pq_node o;      //a dummy

  if (d1 == p2)
  { // the partial children are neighbours

   if (p1->right_most->status == D_NODE_FULL)
      { m1 = p1->right_most;
        n1 = p1->left_most;
       }
   else
      { m1 = p1->left_most;
        n1 = p1->right_most;
       }

   if (p2->right_most->status == D_NODE_FULL)
      { m2 = p2->right_most;
        n2 = p2->left_most;
       }
```

```
    else
       { m2 = p2->left_most;
         n2 = p2->right_most;
        }

    o = (p1->link_one_side == d1) ? p1->link_other_side : p1-
>link_one_side;

    if (m1->link_one_side) m1->link_other_side = m2; else m1-
>link_one_side = m2;
    if (m2->link_one_side) m2->link_other_side = m1; else m2-
>link_one_side = m1;
    if (n1->link_one_side) n1->link_other_side = o;  else n1-
>link_one_side = o;

    if (o)
      if (o->link_one_side == p1)
         o->link_one_side = n1;
      else
         o->link_other_side = n1;

    o = (p2->link_one_side == d2) ? p2->link_other_side : p2-
>link_one_side;

    if (n2->link_one_side)
       n2->link_other_side = o;
    else
       n2->link_one_side = o;

    if (o)
      if (o->link_one_side == p2)
         o->link_one_side = n2;
      else
         o->link_other_side = n2;

    d1 = m2;
    d2 = m1;
                              //reversed and chained
  }
  else
  { // full children between the partial

    if (p1->right_most->status == D_NODE_FULL)
      { m1 = p1->right_most;
        n1 = p1->left_most;
       }
    else
      { m1 = p1->left_most;
        n1 = p1->right_most;
       }

    o = (p1->link_one_side == d1) ? p1->link_other_side : p1-
>link_one_side;

    if (m1->link_one_side)        m1->link_other_side = d1; else m1-
>link_one_side = d1;
    if (d1->link_one_side == p1) d1->link_one_side = m1; else d1-
>link_other_side = m1;
    if (n1->link_one_side)        n1->link_other_side = o;  else n1-
>link_one_side = o;
```

```
   if (o)
      if (o->link_one_side == p1)
         o->link_one_side = n1;
      else
         o->link_other_side = n1;

   if (p2->right_most->status == D_NODE_FULL)
      { m2 = p2->right_most;
        n2 = p2->left_most;
       }
   else
      { m2 = p2->left_most;
        n2 = p2->right_most;
       }

   o = (p2->link_one_side == d2) ? p2->link_other_side : p2-
>link_one_side;

   if (m2->link_one_side)       m2->link_other_side = d2; else m2-
>link_one_side = d2;
   if (d2->link_one_side == p2) d2->link_one_side = m2; else d2-
>link_other_side = m2;
   if (n2->link_one_side)       n2->link_other_side = o;  else n2-
>link_one_side = o;


   if (o)
      if (o->link_one_side == p2)
         o->link_one_side = n2;
      else
         o->link_other_side = n2;

   // reversed and chained
  }

  l = d1;
  k = m1;

  while (k->status == D_NODE_FULL)
  { go_to_sibling(k, l);
    skip_dir(k,l);
  }

  pseudo_root->left_most = l;

  l = d2;
  k = m2;

  while (k->status == D_NODE_FULL)
  { go_to_sibling(k, l);
    skip_dir(k,l);
  }

  pseudo_root->right_most = l;         //end_most of pseudo_root now is
valid

  if (p1 == x->left_most)
    { x->left_most = n1;
      n1->parent = x;
     }
  else
```

```
    if (p2 == x->left_most)
    { x->left_most = n2;
      n2->parent = x;
     }

  if (p1 == x->right_most)
    { x->right_most = n1;
      n1->parent = x;
     }
  else
    if (p2 == x->right_most)
    { x->right_most = n2;
      n2->parent = x;
     }

  if (x != pseudo_root)  x->node_reset();

  pseudo_root->left_most->parent = x;

  delete p1;
  delete p2;

  x->part_child1 = x->part_child2 = NULL;

  return true;
}
```

```
pq_tree::~pq_tree()
{
  if (!successful)  del_subtree(root);
  delete   pseudo_root;
  delete[] leaves;
}
```

```
bool pq_tree::reduction(list<int>& S)
{
 list_item  lit= processed.first();

  if (lit)
  { do  processed.inf(lit)->node_reset();
    while( lit= processed.succ(lit) );

    processed.clear();
  }

  pseudo_root->type = D_NODE_PNODE;
  pseudo_root->node_reset();


  successful = bubble(S) && reduce(S);
```

```
  #ifdef _DEBUG_PQ_TREE
    if (!successful)  show("not successful",root);
  #endif

  return successful;
}



inline void pq_tree::frontier(list<int> &F)
{ F.clear();
  sequence(F, root);
}



void pq_tree::sequence(list<int>& S, pq_node x, pq_node l)
{
  if (x->type == D_NODE_LEAF)
  { S.append(x->leaf_index);
    return;
  }

 pq_node k = x->left_most;
 pq_node r = x->right_most;

   do
   { if (k->type == D_NODE_DIR)
     { int i = S.pop() +1;          // insert one more DIR-ptr in the
sequence S
                                    // with respect to its direction

       if (k->link_one_side == l)
         S.push(k->leaf_index);
       else
         S.push(-k->leaf_index);
       S.push(i);
       processed.push(k);         // we have to delete the DIR-ptr in
update()
     }
     else
       sequence(S,k);

     go_to_sibling(k, l);

   } while (l != r);
}



bool pq_tree::bubble(list<int>& S)
{
  queue<pq_node>  Q;
  pq_node         x, y, z, k, l;
  int              m, blocked_found;

  #ifdef _DEBUG_PQ_TREE
```

```
  cout << endl;
  #endif

  root_reached = 0;
  blocked_chain_count = 0;
  blocked_nodes_count = 0;

  pseudo_root->left_most = NULL;
  pseudo_root->right_most= NULL;

  forall(m, S)
  { x = leaves[m];
    x->mark = D_NODE_QUEUED;  Q.append(x);
  }

  #ifdef _DEBUG_PQ_TREE
  printf(" %d ",this->pseudo_root->leaf_index);
  cons_pq_tree(root,"a","bubble");
  // show("in bubble",root);
  #endif


 while ((Q.size() + blocked_chain_count + root_reached) > 1)
 {
  if (Q.empty())  return false;

  x = Q.pop();

  if ( x->parent_type == D_NODE_PNODE || !x->link_one_side || !x-
>link_other_side)
     x->mark = D_NODE_UNBLOCKED;
  else
    { // try to make it valid in constant time
      x->mark = D_NODE_BLOCKED;
      k = x->link_one_side; l = x;
      skip_dir(k,l);
      if ( k->mark == D_NODE_UNBLOCKED)
        { //the link_one_side-sibling has a valid parent
          x->mark = D_NODE_UNBLOCKED;
          x->parent = k->parent;
        }
      else
        { k = x->link_other_side;  l = x;
          skip_dir(k,l);
          if ( k->mark == D_NODE_UNBLOCKED)
          { //the link_other_side-sibling has a valid parent
            x->mark = D_NODE_UNBLOCKED;
            x->parent = k->parent;
          }
        }
      }

  if (x->mark == D_NODE_UNBLOCKED)
  { //x has got a valid parent
    y = x->parent;
    z = x->link_one_side;
    if ( z && (z->mark == D_NODE_BLOCKED || z->type == D_NODE_DIR) )
    { l = x;
      blocked_found = 0;
      while ( z && (z->mark == D_NODE_BLOCKED || z->type == D_NODE_DIR)
)
```

```
      { if ( z->type != D_NODE_DIR)
        { blocked_found = 1;
          z->parent = y;
          z->mark = D_NODE_UNBLOCKED;
          y->pert_child_count++;
          blocked_nodes_count--;
         }

        go_to_sibling(z, 1);
       }
      if (blocked_found)  blocked_chain_count--;
    }                //to unblock a blocked chain in x->link_one_side
direction

   z = x->link_other_side;

   if ( z && (z->mark == D_NODE_BLOCKED || z->type == D_NODE_DIR) )
   { l = x;
     blocked_found = 0;
     while ( z && (z->mark == D_NODE_BLOCKED || z->type == D_NODE_DIR) )
     { if ( z->type != D_NODE_DIR)
       { blocked_found = 1;
         z->mark = D_NODE_UNBLOCKED;
         z->parent = y;
         y->pert_child_count++;
         blocked_nodes_count--;
       }
       go_to_sibling(z, 1);

     }               //to unblock a blocked chain in x->link_other_side
direction
     if (blocked_found)  blocked_chain_count--;
   }

   if ( !y )
      root_reached = 1;
   else
    { y->pert_child_count++;
      if (y->mark == D_NODE_UNMARKED)
      { Q.append(y);
        y->mark = D_NODE_QUEUED;
       }
     }

  }
  else
  { // x's parent is not valid
    k = x->link_one_side;
    l = x;
    skip_dir(k,l);
    if (k->mark == D_NODE_BLOCKED)  blocked_chain_count--;
    k = x->link_other_side;
    l = x;
    skip_dir(k,l);
    if (k->mark == D_NODE_BLOCKED)  blocked_chain_count--;
    blocked_chain_count++;
    blocked_nodes_count++;
   }

 } //end of "while (Q->size() + blocked_chain_count + root_reached > 1)"
```

```
 if (blocked_chain_count)
 {
   pseudo_root->pert_child_count = blocked_nodes_count;
   pseudo_root->type = D_NODE_QNODE;

   #ifdef _DEBUG_PQ_TREE
//    show("blocked_chain_count am ende von bubble",root);
   #endif

  }

#ifdef _DEBUG_PQ_TREE
//if (pseudo_root->leaf_index > 40)  show("Ende bubble", root);
#endif

 return true;
}




void pq_tree::bubble_reset(pq_node x)
{
  // in case bubble affects the nodes over the pertinent subtree root
  // we have to reset their pert_child_counts

 pq_node k;

//   while (x && x->pert_child_count)            // alt

  while (x && x->pert_child_count && x != pseudo_root)
  {
    if (x->mark == D_NODE_UNBLOCKED) k= x->parent;
      else k= NULL;
    x->pert_child_count = 0;
    x->mark   = D_NODE_UNMARKED;
    x->status= D_NODE_EMPTY;
    x = k;
  }
}




bool pq_tree::reduce(list<int>& S)
{
  queue<pq_node>  Q;
  pq_node         x, y, k, l;

  int              S_size = S.size();
  int              x_type;

//show_pq_tree_test(root);

  while (!S.empty())
  { x = leaves[S.pop()];
    x->pert_leaf_count = 1;
    Q.append(x);
```

```
   }

 while (!Q.empty())
 { x = Q.pop();

#ifdef _DEBUG_PQ_TREE
cons_pq_tree(root,"b","reduce");
int     aaa=0;
#endif

 if (x->mark == D_NODE_BLOCKED)
 { // a blocked chain exists and its members
   // get the "auxiliary" parent pseudo_root

  x->parent = pseudo_root;
  x->mark = D_NODE_UNBLOCKED;

  l = x;
  k = x->link_one_side;
  skip_dir(k, l);

  if (!k || k->mark == D_NODE_UNMARKED)
  { if (pseudo_root->left_most)
       pseudo_root->right_most = l;
    else
       pseudo_root->left_most = l;
    }

  l = x;
  k = x->link_other_side;
  skip_dir(k,l);

  if (!k || k->mark == D_NODE_UNMARKED)
  { if (pseudo_root->left_most)
       pseudo_root->right_most = l;
    else
       pseudo_root->left_most = l;
   }

  if (Q.empty()) pseudo_root->type = D_NODE_QNODE;

 }

#ifdef _DEBUG_PQ_TREE
//if (!aaa && x->type != D_NODE_LEAF) show("in reduce, der momentane
Unterbaum",x);
if (pseudo_root->leaf_index > 40)  show("in reduce, der gesamte Baum",
root);
cout << flush;
#endif

 x_type= x->type;                 // Type may change in template
application

 if (x->pert_leaf_count < S_size)
 {
   if (x != pseudo_root)                 // ist immer true hier ? !
   { y = x->parent;
     y->pert_leaf_count += x->pert_leaf_count;
     if (!(--y->pert_child_count))  Q.append(y);
   }
```

```
    if (x_type == D_NODE_LEAF)
      if (!template_PQL1(x, false)) return false;

    if (x_type == D_NODE_PNODE)
      if (!template_PQL1(x, false))
      if (!template_P3(x, false))
      if (!template_P5(x, false)) return false;

    if (x_type == D_NODE_QNODE)
      if (!template_PQL1(x, false))
      if (!template_Q2(x)) return false;
  }
  else
  {                                  // x is pruned pert subtree root
(PRUNED(T,S))
    pseudo_root->status = D_NODE_FULL;          // ROOT(T,S) reached
    if (x->parent)  bubble_reset(x->parent);

    if (x_type == D_NODE_LEAF)
      if (!template_PQL1(x, true)) return false;

    if (x_type == D_NODE_PNODE)
      if (!template_PQL1(x, true))
      if (!template_P3(x, true))
      if (!template_P5(x, true))
      if (!template_P6(x)) return false;

    if (x_type == D_NODE_QNODE)
      if (!template_PQL1(x, true))
      if (!template_Q2(x))
      if (!template_Q3(x)) return false;
  }

  }        // while Q not empty

#ifdef _DEBUG_PQ_TREE
cons_pq_tree(root,"b","reduce 2");
//show("in reduce, der gesamte Baum nach Reduction", root);
#endif

return true;

}




void pq_tree::pert_sequence(list<int> &S)
{

#ifdef _DEBUG_PQ_TREE
  if (!pseudo_root->left_most){
   cout << "pseudo_root->left_most gleich NULL in pert_sequence" <<
endl;
   exit(1);
  }
#endif

  pq_node l = pseudo_root->left_most;
```

```
  pq_node k;

  S.clear();
  S.push(0);                    // preparation

  if (l == pseudo_root->right_most)
                                // if pseudo_root has only one child life is
easy.
  { sequence(S, l);
    return;
  }

        // Otherwise we have to find the direction to pseudo_root-
>right_most.
        // Note that an endmost of pseudo_root not necessary has any
NULL-link.

  if (l->link_one_side)
  { k = l->link_one_side;
    skip_dir(k,l);
    l = (k && k->status == D_NODE_FULL)
        ? pseudo_root->left_most->link_other_side
        : pseudo_root->left_most->link_one_side;
  }
  else
    l = NULL;

  // The direction is detected, we can scan the sequence S.

  sequence(S, pseudo_root, l);
}



void pq_tree::leaves_double()
{
        // if any leaf_index > leaves_size occurs we double the size of
array
        // leaves, copy the content of the old array in the lower half
of
        // the new and delete the old. Initially leaves_size is 16.
        // Maybe the user had told the total number of leaves while
defining
        // his PQ tree.

  if (leaves_size)
  { int  i;

    pq_node* A = new pq_node[2 * leaves_size];
    if (!A) error_handler(1,"pq_tree: out of memory");

    for (i=0; i < leaves_size; i++)  A[i] = leaves[i];
    leaves_size *= 2;
    while (i < leaves_size)  A[i++] = NULL;
    delete[]  leaves;
    leaves = A;
  }
  else  leaves_init(32);

 return;
```

```
}


void pq_tree::leaves_init(int lsize)
{
  leaves_size = lsize;

  leaves = new pq_node[leaves_size];
  if (!leaves)  error_handler(1, "pq_tree: out of memory");
  for(int i = 0; i < leaves_size; i++)  leaves[i] = NULL;
}



void pq_tree::del_pert_subtree()
{
  pq_node k = pseudo_root->left_most;
  pq_node l = NULL;

  while (k && k != pseudo_root->right_most)
  { go_to_sibling(k, l);
    del_subtree(l); // Note that also l is deleted in this function
call.
                    // But to progress correctly in the chain we need
l's
                    // value (see previous command).
  }
}


        // loescht alle Kinder von x und dann x selber:

void pq_tree::del_subtree(pq_node x)
{
  pq_node k = x->left_most;
  pq_node l = NULL;

  while (k)
  { //Note that the value of l is essentially for the loop
    //but the pointer l is not valid
    //(see also the comment in del_pert_subtree() ).

    go_to_sibling(k, l);
    del_subtree(l);     //delete the subtree recursivly
  }

  delete x;

}



bool pq_tree::update(list<int>& S)
{
 int       i=0;
```

```
 pq_node  v, w, k= NULL, l;

  if (S.empty())
  {     // delete the pert. subtree contained in processed...

    while (!processed.empty())
    { w = processed.pop();
      if (w->type == D_NODE_LEAF)  leaves[w->leaf_index] = NULL;
      delete w;
    }

        // if there's anything else in the PQ_tree the reduction has
failed.

    for(i=0; i < leaves_size && !leaves[i]; i++);

   return (i == leaves_size);
  }

  if (root && (pseudo_root->left_most == root))
  { // A special case requires special treatment.
    // Note that pseudo_root has only 1 child in this case.

    while (!processed.empty())
    { w = processed.pop();
      if (w->type == D_NODE_LEAF) leaves[w->leaf_index] = NULL;
      delete w;
    }

        // The pertinent subtree, here that means the whole pq_tree
        // is deleted. The application has failed.
    return false;
  }

  i = 0;
  v = new pq_node_struct;

  if (pseudo_root->left_most &&
      pseudo_root->left_most->parent_type == D_NODE_PNODE)
  { v->parent_type = D_NODE_PNODE;
    v->parent = pseudo_root->left_most->parent;
  }
  else
    if (pseudo_root->left_most)  v->parent_type = D_NODE_QNODE;

  if (S.size() == 1)
  {                                             // then create v as a
leaf
    v->leaf_index = S.pop();

    while (v->leaf_index >= leaves_size) leaves_double();

    if (leaves[v->leaf_index]) return false;

    leaves[v->leaf_index] = v;
    v->type = D_NODE_LEAF;
  }
  else
  {   //then create v as a P-node with leaves labelled with the elements
of S
                  //  v->leaf_index = pseudo_root->leaf_index;
```

```
                    //only for testing

      v->type = D_NODE_PNODE;
      v->child_count = S.size();
      v->left_most = l = new pq_node_struct;
      l->link_one_side = NULL;
      l->parent = v;
      l->leaf_index = S.pop();

      while (l->leaf_index >= leaves_size) leaves_double();

      if (leaves[l->leaf_index])  return false;

      leaves[l->leaf_index]=l;
      l->parent_type = D_NODE_PNODE;
      l->type = D_NODE_LEAF;

      while (!S.empty())
      { l->link_other_side = k = new pq_node_struct;
        k->leaf_index = S.pop();

        while (k->leaf_index >= leaves_size)  leaves_double();

        if (leaves[k->leaf_index])  return false;

        leaves[k->leaf_index] = k;
        k->parent_type = D_NODE_PNODE;
        k->type = D_NODE_LEAF;
        k->parent = v;
        k->link_one_side = l;
        l = k;
      }
      k->link_other_side = NULL;
      v->right_most = k;
  }

  if (!root)
  {                          //then the pq_tree is just constructed & still
empty
    root = v;
    v->parent_type = D_NODE_QNODE;              // *** warum ?
    return true;
  }

                             //replace the full chain under pseudo_root by
v
  k = pseudo_root->left_most;
  l = pseudo_root->right_most;

  if (k == l)              //then pseudo_root has only one child
    replace_in_siblings(k, v);
  else
  {
     pq_node  k1, l1;

     if (k->link_one_side && k->link_other_side)
     {   // Then k has a full and an empty sibling.
         // The full is contained in the pertinent subtree and to be
         // deleted. The empty becomes a sibling of v.

      if (k->link_one_side->status == D_NODE_EMPTY &&
```

```
      k->link_one_side->type != D_NODE_DIR)
        v->link_one_side = k->link_one_side;
  else
     if (k->link_other_side->status == D_NODE_EMPTY &&
         k->link_other_side->type != D_NODE_DIR)
            v->link_one_side = k->link_other_side;
     else
        if (k->link_one_side->status == D_NODE_FULL)
           v->link_one_side = k->link_other_side;
        else
           if (k->link_other_side->status == D_NODE_FULL)
              v->link_one_side = k->link_one_side;
           else
            { k1 = k->link_one_side;  l1 = k;
              skip_dir(k1,l1);
              if (k1->status == D_NODE_EMPTY)
                 v->link_one_side = k->link_one_side;
              else
                 v->link_one_side = k->link_other_side;
            }

    if (v->link_one_side->link_one_side == k)
        v->link_one_side->link_one_side = v;
    else
        v->link_one_side->link_other_side = v;
  }
  else
  {                            // then k is an endmost of his real
father
     v->link_one_side = NULL;
     if (k->parent->right_most == k)
        k->parent->right_most = v;
     else
        k->parent->left_most = v;

     v->parent = k->parent;
   }

     // v is chained instead of k.

  if (l->link_one_side && l->link_other_side)
  {                         // analogous to treatment of k, as above
     if (l->link_one_side->status == D_NODE_EMPTY &&
         l->link_one_side->type != D_NODE_DIR)
           v->link_other_side = l->link_one_side;
     else
        if (l->link_other_side->status == D_NODE_EMPTY &&
            l->link_other_side->type != D_NODE_DIR)
              v->link_other_side = l->link_other_side;
        else
           if (l->link_one_side->status == D_NODE_FULL)
              v->link_other_side = l->link_other_side;
           else
              if (l->link_other_side->status == D_NODE_FULL)
                 v->link_other_side = l->link_one_side;
              else
               { k1 = l->link_one_side;  l1 = l;
                 skip_dir(k1,l1);
                 if (k1->status == D_NODE_EMPTY)
                    v->link_other_side = l->link_one_side;
                 else
```

```
                    v->link_other_side = l->link_other_side;
                }
        if (v->link_other_side->link_one_side == l)
            v->link_other_side->link_one_side = v;
        else
            v->link_other_side->link_other_side = v;
      }
    else
      {                     //then l is an endmost of his real father
        v->link_other_side = NULL;
        if (l->parent->right_most == l)
           l->parent->right_most = v;
        else
           l->parent->left_most = v;

        v->parent = l->parent;
      }
    // v is chained instead of l.

   }

        // Now v replaces the chain of full nodes beyond
        // the real father.

        // v is in the scanning direction of the pert subtree
        // and if necessary we can add a DIR-ptr

   if (pseudo_root->left_most->parent_type == D_NODE_QNODE)
   {
     k = new pq_node_struct;

     k->leaf_index = pseudo_root->leaf_index;
     k->type = D_NODE_DIR;         // insert a DIR-ptr, but not as an
end_most
     if (v->link_one_side)
       { k->link_one_side = v->link_one_side;
         v->link_one_side = k;
         k->link_other_side = v;
         k->link_one_side->link_one_side == v ?
          (k->link_one_side->link_one_side = k) :
          (k->link_one_side->link_other_side = k);
       }
     else
       { k->link_other_side = v->link_other_side;
         v->link_other_side = k;
         k->link_one_side = v;
         k->link_other_side->link_one_side == v ?
         (k->link_other_side->link_one_side = k) :
         (k->link_other_side->link_other_side = k);
       }
   }

        // Prepare pseudo_root for the next possible DIR-ptr

   pseudo_root->leaf_index++;
   pseudo_root->mark = D_NODE_UNMARKED;
   pseudo_root->status = D_NODE_EMPTY;

        // Now we delete the pertinent subtree.

   while (!processed.empty())
```

```
    { w = processed.pop();
      if (w->type == D_NODE_LEAF) leaves[w->leaf_index] = NULL;
      delete w;
    }

#ifdef _DEBUG_PQ_TREE
  cons_pq_tree(root,"b","update");
#endif

 return true;
}
```

```
// h"aufig vorkommende Aktionen:


inline void pq_tree::skip_dir(pq_node& k, pq_node& last_k)
                                                          // skip direction
indicators
{
  while (k && k->type == D_NODE_DIR)
    go_to_sibling(k, last_k);
}


inline void pq_tree::go_to_sibling(pq_node& k, pq_node& last_k)
{
  if (k->link_one_side == last_k)
  {
    last_k = k;
    k = k->link_other_side;
  }
  else
  { last_k = k;
    k = k->link_one_side;
  }
}
```

```
/**************************************************************************
********
+
+  LEDA 3.5.1
+
+  _d2_spring.c
+
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+
**************************************************************************
*******/
#include <LEDA/graph_alg.h>

#include <math.h>
#include <LEDA/array2.h>


static float log_2(int x)
{ float l = 0;
  while (x)
  { l++;
    x >>= 1;
   }
  return l/2;
}



void D2_SPRING_EMBEDDING(const graph& G, node_array<double>& xpos,
                                         node_array<double>& ypos,
                                         double xleft, double xright,
                                         double ybottom, double ytop,
                                         int iterations)
{ double width  = xright - xleft;
  double height = ytop - ybottom;

  for (int count = 1; count < iterations; count++)
  {
    double k = sqrt(width*height / G.number_of_nodes()) / 2;

    //float l2 = 50*log_2(1+count);

    float l2 = 25*log_2(1+count);

    double tx = width  / l2;
    double ty = height / l2;

    node_array<double>  xdisp(G,0);
    node_array<double>  ydisp(G,0);

   // repulsive forces

   node v;
```

```
forall_nodes(v,G)
{
  double xv = xpos[v];
  double yv = ypos[v];

  node u;
  forall_nodes(u,G)
  { if(u == v) continue;
    double xdist = xv - xpos[u];
    double ydist = yv - ypos[u];

    double dist = xdist * xdist + ydist * ydist;

    if (dist < 1e-3) dist = 1e-3;

    double frepulse = k*k/dist;

    xdisp[v] += frepulse * xdist;
    ydisp[v] += frepulse * ydist;
   }

  //xdisp[v] *=  (double(rand_int(750,1250))/1000.0);
  //ydisp[v] *=  (double(rand_int(750,1250))/1000.0);
}


// attractive forces

edge e;
forall_edges(e,G)
{ node u = G.source(e);
  node v = G.target(e);

  double xdist=xpos[v]-xpos[u];
  double ydist=ypos[v]-ypos[u];

  double dist=sqrt(xdist*xdist+ydist*ydist);

  float f = (G.degree(u)+G.degree(v))/16.0;

  dist /= f;

  xdisp[v]-=xdist*dist/k;
  ydisp[v]-=ydist*dist/k;
  xdisp[u]+=xdist*dist/k;
  ydisp[u]+=ydist*dist/k;
 }


// preventions

forall_nodes(v,G)
{ double xd = xdisp[v];
  double yd = ydisp[v];

  double dist = sqrt(xd*xd+yd*yd);

  xd = tx*xd/dist;
  yd = ty*yd/dist;

  double xp = xpos[v] + xd;
```

```
      double yp = ypos[v] + yd;

      //if (xp > xleft && xp < xright)
          xpos[v] = xp;
      //if (yp > ybottom && yp < ytop)
          ypos[v] = yp;
    }
  }
}



void D2_SPRING_EMBEDDING1(const graph& G, node_array<double>& xpos,
                                          node_array<double>& ypos,
                                          double xleft, double xright,
                                          double ybottom, double ytop,
                                          int iterations)
{ double width  = xright - xleft;
  double height = ytop - ybottom;

  for (int count = 1; count < iterations; count++)
  {
    double k = sqrt(width*height / G.number_of_nodes()) / 2;

    //float l2 = 50*log_2(1+count);

    float l2 = 25*log_2(1+count);

    double tx = width  / l2;
    double ty = height / l2;

    node_array<double>  xdisp(G,0);
    node_array<double>  ydisp(G,0);

   // repulsive forces

   node v;
   forall_nodes(v,G)
   { double xv = xpos[v];
     double yv = ypos[v];
     node u;
     forall_nodes(u,G)
     { if(u == v) continue;
       double xdist = xv - xpos[u];
       double ydist = yv - ypos[u];
       double dist = xdist * xdist + ydist * ydist;
       if (dist < 1e-3) dist = 1e-3;
       double frepulse = k*k/dist;
       xdisp[v] += frepulse * xdist;
       ydisp[v] += frepulse * ydist;
      }

     edge e;
     forall_edges(e,G)
     { node a = source(e);
       node b = target(e);
       if (a == v || b == v) continue;
       double xdist = xv - (xpos[a]+xpos[b])/2;
       double ydist = yv - (ypos[a]+ypos[b])/2;
       double dist = xdist * xdist + ydist * ydist;
       if (dist < 1e-3) dist = 1e-3;
```

```
        double frepulse = k*k/dist;
        xdisp[v] += frepulse * xdist;
        ydisp[v] += frepulse * ydist;
       }
    }


    // attractive forces

    edge e;
    forall_edges(e,G)
    { node u = G.source(e);
      node v = G.target(e);

      double xdist=xpos[v]-xpos[u];
      double ydist=ypos[v]-ypos[u];

      double dist=sqrt(xdist*xdist+ydist*ydist);

      float f = (G.degree(u)+G.degree(v))/16.0;

      dist /= f;

      xdisp[v]-=xdist*dist/k;
      ydisp[v]-=ydist*dist/k;
      xdisp[u]+=xdist*dist/k;
      ydisp[u]+=ydist*dist/k;
     }


    // preventions

    forall_nodes(v,G)
    { double xd = xdisp[v];
      double yd = ydisp[v];

      double dist = sqrt(xd*xd+yd*yd);

      xd = tx*xd/dist;
      yd = ty*yd/dist;

      double xp = xpos[v] + xd;
      double yp = ypos[v] + yd;

      //if (xp > xleft && xp < xright)
          xpos[v] = xp;
      //if (yp > ybottom && yp < ytop)
          ypos[v] = yp;
     }
   }
}
```

```
/***********************************************************************
********
+
+  LEDA 3.5.1
+
+  _d3_spring.c
+
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+
***********************************************************************
*******/
#include <LEDA/graph_alg.h>

#include <math.h>
#include <LEDA/array2.h>


static float log_2(int x)
{ float l = 0;
  while (x)
  { l++;
    x >>= 1;
   }
  return l/2;
}


void D3_SPRING_EMBEDDING(const graph& G, node_array<double>& xpos,
                                         node_array<double>& ypos,
                                         node_array<double>& zpos,
                                         double xleft, double xright,
                                         double ybottom, double ytop,
                                         double zbottom, double ztop,
                                         int iterations)
{ list<node> L;
  D3_SPRING_EMBEDDING(G,L,xpos,ypos,zpos,

xleft,xright,ybottom,ytop,zbottom,ztop,iterations); }


void D3_SPRING_EMBEDDING(const graph& G, const list<node>& fixed_nodes,
                                         node_array<double>& xpos,
                                         node_array<double>& ypos,
                                         node_array<double>& zpos,
                                         double xleft, double xright,
                                         double ybottom, double ytop,
                                         double zbottom, double ztop,
                                         int iterations)
{

  if (xleft >= xright || ybottom >= ytop || zbottom >= ztop)
      error_handler(1,"SPRING_EMBDDING: illegal bounds.");
```

```
double width  = xright - xleft;
double height = ytop - ybottom;
double depth  = ztop - zbottom;

for (int count = 1; count < iterations; count++)
{
  double k = sqrt(width*height / G.number_of_nodes()) / 2;

  float l2 = 50*log_2(1+count);

  double tx = width  / l2;
  double ty = height / l2;
  double tz = depth  / l2;

  node_array<double>  xdisp(G,0);
  node_array<double>  ydisp(G,0);
  node_array<double>  zdisp(G,0);

 // repulsive forces

 node v;
 forall_nodes(v,G)
 { int i = int((xpos[v] - xleft) / k);
   int j = int((ypos[v] - ybottom) / k);

   double xv = xpos[v];
   double yv = ypos[v];
   double zv = zpos[v];

   node u;
   forall_nodes(u,G)
   { if(u == v) continue;
     double xdist = xv - xpos[u];
     double ydist = yv - ypos[u];
     double zdist = zv - zpos[u];

     double dist = xdist * xdist + ydist * ydist + zdist * zdist;

     if (dist < 1e-3) dist = 1e-3;

     double frepulse = k*k/dist;

     xdisp[v] += frepulse * xdist;
     ydisp[v] += frepulse * ydist;
     zdisp[v] += frepulse * zdist;
      }
  //xdisp[v] *=  (double(rand_int(750,1250))/1000.0);
  //ydisp[v] *=  (double(rand_int(750,1250))/1000.0);
  //zdisp[v] *=  (double(rand_int(750,1250))/1000.0);
 }


 // attractive forces

 edge e;
 forall_edges(e,G)
 { node u = G.source(e);
   node v = G.target(e);

   double xdist=xpos[v]-xpos[u];
```

```
        double ydist=ypos[v]-ypos[u];
        double zdist=zpos[v]-zpos[u];

        double dist=sqrt(xdist*xdist+ydist*ydist+zdist*zdist);

        float f = (G.degree(u)+G.degree(v))/16.0;

        dist /= f;

        xdisp[v]-=xdist*dist/k;
        ydisp[v]-=ydist*dist/k;
        zdisp[v]-=zdist*dist/k;
        xdisp[u]+=xdist*dist/k;
        ydisp[u]+=ydist*dist/k;
        zdisp[u]+=zdist*dist/k;
       }


    // preventions

    forall_nodes(v,G)
    { double xd = xdisp[v];
      double yd = ydisp[v];
      double zd = zdisp[v];

      double dist = sqrt(xd*xd+yd*yd+zd*zd);

      xd = tx*xd/dist;
      yd = ty*yd/dist;
      zd = tz*zd/dist;

      double xp = xpos[v] + xd;
      double yp = ypos[v] + yd;
      double zp = zpos[v] + zd;

      if (xp > xleft && xp < xright) xpos[v] = xp;
      if (yp > ybottom && yp < ytop) ypos[v] = yp;
      if (zp > zbottom && zp < ztop) zpos[v] = zp;
     }
   }

}
```

```
/**************************************************************************
*******
+
+  LEDA 3.5.1
+
+  _embed1.c
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+
**************************************************************************
*******/

//------------------------------------------------------------------------
--------
//
// straight line embedding
//
// K. Mehlhorn (1989)
//------------------------------------------------------------------------
--------


#include <LEDA/graph_alg.h>


const int A = -2;
const int B = -1;

static node_array<list_item>  Classloc;
static node_array<int>  ord, labelled, Class;
static node_array<node> first, second, last;

void label_node(graph& G, list<node>& L, int& count,
                list<node>& Al,list<node>& Bl,list<node>*& Il,
                node v, node c)

{ // labels the node v; c is the special node which is to be labelled
  // last; the details are described in lemma 10
  edge e;
  L.append(v);
  ord[v]=count++;
  labelled[v]=1;

  forall_adj_edges(e,v)
  { edge e1 = G.reversal(e);
    node tt = target(e);
    int i;

    if (labelled[tt] && !labelled[target(G.cyclic_adj_succ(e))])
      { first[v]=tt;
        second[v]=target(G.cyclic_adj_pred(e));
       }
```

```
    if (labelled[tt] && !labelled[target(G.cyclic_adj_pred(e))])
last[v]=tt;

    if (!labelled[tt] && (tt != c))
      { if (Class[tt] == A)
          { Al.del(Classloc[tt]);
            Classloc[tt] = Bl.push(tt);
            Class[tt]=B;
           }
        else
          { if (Class[tt] == B)
               { Bl.del(Classloc[tt]);
                 i = 2-labelled[target(G.cyclic_adj_succ(e1))]
                      -labelled[target(G.cyclic_adj_pred(e1))];
                }
            else
               { i=Class[tt];
                 Il[i].del(Classloc[tt]);
                 i = i+1-labelled[target(G.cyclic_adj_succ(e1))]
                        -labelled[target(G.cyclic_adj_pred(e1))];
                }

             Class[tt]=i;
             Classloc[tt]=Il[i].push(tt);

           }//end else case

      }//end if

  }//end

}//end of label_node


void compute_labelling(graph& G,list<node>& L, list<node>& Pi)
{ /* computes the ordering of lemma 10 in List L ,the sequence pi
     in List Pi, the function L^-1(v) in Array ord, and the functions
     first,second,last of lemma 11 in the corresponding Arrays
   */
  node v,a,b,c;

  /* zuerst berechne ich die drei Knoten,die am Rand des aeusseren
     Gebiets liegen sollen
   */

  a=G.first_node();
  list<edge> temp = G.adj_edges(a);
  b = target(temp.pop());
  c = target(temp.pop());


/*
  node_array<int> labelled(G,0);
*/

  labelled.init(G,0);

  int count = 0;

  list<node> Al ;
```

```
/*
  node_array<int> Class(G);
  node_array<list_item> Classloc(G);
*/

  Class.init(G);
  Classloc.init(G);

  forall_nodes(v,G) { Classloc[v] = Al.push(v);Class[v]=A;}

  list<node> Bl;
  list<node>* Il = new list<node>[G.number_of_nodes()];

  label_node(G,L,count,Al,Bl,Il,a,c);
  label_node(G,L,count,Al,Bl,Il,b,c);

  while ( !Il[1].empty() )
  { node v = Il[1].pop();
    label_node(G,L,count,Al,Bl,Il,v,c);
   }

  label_node(G,L,count,Al,Bl,Il,c,c);

   //nun berechne ich noch first second und last des Knoten c
  first[c]=a;
  last[c]=b;

  edge e;
  forall_adj_edges(e,c) if (target(e)==a)
second[c]=target(G.cyclic_adj_pred(e));

 //nun die Folge Pi
  node_array<list_item> Piloc(G);
  Piloc[a] = Pi.push(a);
  Piloc[b] = Pi.append(b);
  forall(v,L) if (v != a && v != b) Piloc[v] =
Pi.insert(v,Piloc[second[v]],-1);

}//end of compute_labelling

void move_to_the_right(list<node>& Pi, node v, node w,
                       node_array<int>& ord, node_array<int>& x)

{ //increases the x-coordinate of all nodes which follow w in List Pi
  //and precede v in List L,i.e., have a smaller ord value than v
  int seen_w = 0;
  node z;
  forall(z,Pi)
  { if (z==w) seen_w=1;
    if (seen_w && (ord[z]<ord[v])) x[z]=x[z]+1;
  }
}


int STRAIGHT_LINE_EMBEDDING(graph& G,node_array<int>& x,
node_array<int>& y)
{
 // computes a straight-line embedding of the planar map G into
 // the 2n by n grid. The coordinates of the nodes are returned
 // in the Arrays x and y. Returns the maximal coordinate.
```

```
if (G.empty()) return 0;

if (G.number_of_nodes() == 1)
{ node v = G.first_node();
  x[v] = y[v] = 1;
  return 1;
 }

list<node> L;
list<node> Pi;
list<edge> TL;

node v;
edge e;
int maxcoord = 1;

/*
node_array<int>  ord(G);
node_array<node> first(G), second(G), last(G);
*/

ord.init(G);
first.init(G);
second.init(G);
last.init(G);


TL = G.triangulate_map();

if (!G.make_map())
  error_handler(1,"STRAIGHT LINE EMBEDDING: graph must be a planar
map");


compute_labelling(G,L,Pi);


//I now embed the first three nodes

v = L.pop();
x[v] = 0;
y[v] = 0;

if (!L.empty())
{ v = L.pop();
  x[v] = 2;
  y[v] = 0;
 }

if (!L.empty())
{ v = L.pop();
  x[v] = 1;
  y[v] = 1;
 }

//I now embed the remaining nodes

while ( !L.empty() )
 {
   v = L.pop();
```

```
    // I first move the nodes depending on second[v] by one unit
    // and the the nodes depending on last[v] by another unit to the
    // right


    move_to_the_right(Pi,v,second[v],ord,x);
    move_to_the_right(Pi,v,last[v],ord,x);

    // I now embed v at the intersection of the line with slope +1
    // through first[v] and the line with slope -1 through last[v]

    int x_first_v = x[first[v]];
    int x_last_v =  x[last[v]];
    int y_first_v = y[first[v]];
    int y_last_v =  y[last[v]];

    x[v]=(y_last_v - y_first_v + x_first_v + x_last_v)/2;
    y[v]=(x_last_v - x_first_v + y_first_v + y_last_v)/2;
 }

// delete triangulation edges

forall(e,TL) G.del_edge(e);

forall_nodes(v,G) maxcoord = Max(maxcoord,Max(x[v],y[v]));

return maxcoord;

}


void STRAIGHT_LINE_EMBEDDING(graph& G,node_array<double>& x,
node_array<double>& y)
{
  node_array<int> x0(G);
  node_array<int> y0(G);

  int maxc = STRAIGHT_LINE_EMBEDDING(G,x0,y0);

  node v;
  forall_nodes(v,G)
  { x[v] = double(x0[v])/maxc;
    y[v] = double(y0[v])/maxc;
   }
}
```

```
/*******************************************************************************
********
+
+  LEDA 3.5.1
+
+  _embed2.c
+
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+
*******************************************************************************
*******/

//-----------------------------------------------------------------------------
---
// Dirk Ambras  1995
//-----------------------------------------------------------------------------
---


#include <LEDA/graph_alg.h>

static void Contract(graph& G, node a, node b , node c, list<node>& L)
{
  node                v,w;
  list<node>         cand;
  node_array<bool> marked(G,false);            // betrachtete Knoten
  node_array<int>  deg(G,0);                    // # virtuelle Nachbarn

  int N = G.number_of_edges();

  marked[a] = marked[b] = marked[c] = true;                    // Init

  deg[a] = deg[b] = deg[c] = N;

  forall_adj_nodes(v,a)
  { marked[v]=true;
    forall_adj_nodes(w,v) deg[w]++;        // mache v bekannt bei den w's
   }

  { forall_adj_nodes(v,a)                         // lade Kandidaten
      if (deg[v]<=2) cand.append(v);
   }

  while (!cand.empty())
  {  node u=cand.pop();
     if (deg[u] == 2)
     {  L.push(u);
        deg[u]=N;
      forall_adj_nodes(v, u)
      { deg[v]--;                  // u ist virtuell geloescht
          if (!marked[v])                // v ist neuer Nachbar von a
          { marked[v]=true;
```

```
            forall_adj_nodes(w,v) deg[w]++;      // mache v bekannt bei
den w's
            if (deg[v] <= 2) cand.append(v);     // lade Kandidaten
          } else
          if (deg[v] == 2) cand.append(v);
        }
      }
    }
}


static void Realizer(graph& G, const list<node>& L,
                     node a, node b, node c,
                     GRAPH<node, int>& T, node_array<node>& v_in_T)
{
  int  i=0;
  node v;
  edge e;
  node_array<int> ord(G,0);

  ord[b] = i++;
  ord[c] = i++;
  node u;
  forall(u,L) ord[u]=i++;                              // V(G) numerieren
  ord[a] = i++;

  forall_nodes(v, G) v_in_T[v] = T.new_node();         // T = copy of G

  forall(v, L)
  { node u = v_in_T[v];    // u is copy of v in T

    forall_adj_edges(e, v)
       if (ord[G.target(e)] > ord[v]) break;

    edge e1 = e;
    while(ord[G.target(e1)] > ord[v]) e1 = G.cyclic_adj_succ(e1);
    T.new_edge(v_in_T[G.target(e1)], u, 2);

    edge e2 = e;
    while(ord[G.target(e2)] > ord[v]) e2 = G.cyclic_adj_pred(e2);
    T.new_edge(v_in_T[G.target(e2)], u, 3);

    for(e=G.cyclic_adj_succ(e1); e != e2; e=G.cyclic_adj_succ(e))
      T.new_edge(u, v_in_T[G.target(e)], 1);
  }

  // special treatement of a,b,c

  node a_in_T = v_in_T[a];
  node b_in_T = v_in_T[b];
  node c_in_T = v_in_T[c];

  forall_adj_edges(e,a)
  T.new_edge(a_in_T, v_in_T[G.target(e)], 1);

  T.new_edge(b_in_T, a_in_T, 2);
  T.new_edge(b_in_T, c_in_T, 2);

  T.new_edge(c_in_T, a_in_T, 3);
  T.new_edge(c_in_T, b_in_T, 3);
```

```
}


static void Subtree_Sizes(GRAPH<node, int>& T, int i, node r,
                                node_array<int>& size)
{
  // computes sizes of all subtrees of tree with root r in T(i)

  int  sum=0;
  edge e;
  forall_adj_edges(e, r)
    if (T[e]==i)
    { node w=T.target(e);
      Subtree_Sizes(T, i, w, size);
      sum+=size[w];
    }
  size[r]=sum+1;
}


static void Prefix_Sum(GRAPH<node, int>& T, int i, node r,
                       const node_array<int>& val, node_array<int>& sum)
{

  // computes for every node u in the subtree of T(i) with root r
  // the sum of all val[v] where v is a node on the path from r to u

  list<node> Q;

  Q.append(r);
  sum[r] = val[r];

  while (!Q.empty())
  { node v=Q.pop();
    edge e;
    forall_adj_edges(e, v)
      if (T[e] == i)
      { node w=T.target(e);
        Q.append(w);
        sum[w] = val[w] + sum[v];
      }
  }
}


int STRAIGHT_LINE_EMBEDDING2(graph& G,node_array<int>& xcoord,
                                      node_array<int>& ycoord)
{
  int n = G.number_of_nodes();

  if (n < 3)
  { int max_c = 1;
    if (n > 0)
    { node a = G.first_node();
      xcoord[a] = 1;
      ycoord[a] = 1;
     }
    if (n > 1)
    { node b = G.last_node();
      xcoord[b] = 2;
      ycoord[b] = 2;
```

```
    max_c = 2;
   }
  return max_c;
 }

node              v;
list<node>        L;
GRAPH<node, int> T;
node_array<node> v_in_T(G);


list<edge> el = G.triangulate_map();

// choose outer face a,b,c


node a=G.first_node();
edge e=G.first_adj_edge(a);
node c=G.target(e);
node b = G.target(G.adj_succ(e));


Contract(G,a,b,c,L);

Realizer(G,L,a,b,c,T,v_in_T);                          // T aufbauen

node_array<int>  t1(T);
node_array<int>  t2(T);
node_array<int>  val(T,1);

node_array<int>  P1(T);
node_array<int>  P3(T);
node_array<int>  v1(T);
node_array<int>  v2(T);

Subtree_Sizes(T, 1, v_in_T[a], t1);
Subtree_Sizes(T, 2, v_in_T[b], t2);

Prefix_Sum(T, 1, v_in_T[a], val, P1);
Prefix_Sum(T, 3, v_in_T[c], val, P3);
// now Pi  =  depth of all nodes in Tree T(i) (depth[root] = 1)


Prefix_Sum(T, 2, v_in_T[b], t1, v1);
v1[v_in_T[a]] = t1[v_in_T[a]];     // Sonderrolle von a

// in v1[v] steht jetzt die Summe (Anzahl der Knoten im T1-UBaum[x])
// fuer jeden Knoten x im Pfad in T2 von b nach v

Prefix_Sum(T, 3, v_in_T[c], t1, val);
val[v_in_T[a]]=t1[v_in_T[a]];                          // Sonderrolle von
a

// in val[v] steht jetzt die Summe (Anzahl der Knoten im T1-UBaum[x])
// fuer jeden Knoten x im Pfad in T3 von c nach v
// es ist r1[v]=v1[v]+val[v]-t1[v] die Anzahl der Knoten in der
// Region 1 von v

forall_nodes(v, T) v1[v] += val[v]-t1[v]-P3[v];     // v1' errechnen

Prefix_Sum(T, 3, v_in_T[c], t2, v2);
```

```
  v2[v_in_T[b]]=t2[v_in_T[b]];                              // Sonderrolle von
b

  Prefix_Sum(T, 1, v_in_T[a], t2, val);
  val[v_in_T[b]]=t2[v_in_T[b]];                             // Sonderrolle von
b

  forall_nodes(v, T) v2[v] += val[v]-t2[v]-P1[v];           // v2' errechnen

  int maxcoord = 0;

  forall_nodes(v, G)                                  // x- & y-Feld kopieren
  { xcoord[v] = v1[v_in_T[v]];
    ycoord[v] = v2[v_in_T[v]];
    maxcoord = Max(maxcoord,Max(xcoord[v],ycoord[v]));
   }

  forall(e, el) G.del_edge(e);                                    //
eingefuegte Kanten
                                                             // loeschen
  return maxcoord;
}


void STRAIGHT_LINE_EMBEDDING2(graph& G,node_array<double>& x,
node_array<double>& y)
{
  node_array<int> x0(G);
  node_array<int> y0(G);

  int maxc = STRAIGHT_LINE_EMBEDDING2(G,x0,y0);

  node v;
  forall_nodes(v,G)
  { x[v] = double(x0[v])/maxc;
    y[v] = double(y0[v])/maxc;
   }
}
```

```
/***********************************************************************
********
+
+  LEDA 3.5.1
+
+  _ortho.c
+
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+
************************************************************************
*******/

#include <LEDA/planar_map.h>
#include <LEDA/node_map.h>
#include <LEDA/edge_map.h>
#include <LEDA/face_map.h>
#include <LEDA/stack.h>
#include <LEDA/graph_alg.h>

#define EPS ""
#define INFINITY MAXINT
#define REV(e) P.reversal(e)
#define SUCC(e) P.face_cycle_succ(e)
#define PRED(e) P.face_cycle_pred(e)
#define IS_CAGE(f)   (P.get_cage(P.first_face_edge(f)))
#define IS_OUTER(f)  (!P.get_inner(P.first_face_edge(f)))
#define NEXT(d)  ((direction)((d+5)%4))
#define PREV(d)  ((direction)((d+3)%4))
#define OPP(d)   ((direction)((d+6)%4))

#define ERR_EMPTY_GRAPH           "ORTHO: input graph is empty"
#define ERR_NOT_CONNECTED         "ORTHO: input graph is not connected"
#define ERR_NO_PLANAR_MAP         "ORTHO: this is no planar map"
#define ERR_INVALID_NETWORK       "ORTHO: invalid network"
#define ERR_NO_FEASIBLE_FLOW      "ORTHO: no feasible flow"
#define ERR_NO_ORTHO_REP          "ORTHO: orthogonal rep. not valid"
#define ERR_BAD_STRING            "ORTHO: trying to set nonempty string"
#define ERR_BAD_ANGLE             "ORTHO: bad angle"
#define ERR_BAD_DIRECTION         "ORTHO: bad direction"
#define ERR_OPEN_CPLEX_ENV        "CPLEX: failed to open environment"
#define ERR_LOAD_LP               "CPLEX: failed to load LP"
#define ERR_CPLEX_ADD_ROWS        "CPLEX: CPXaddrows failed"
#define ERR_CPLEX_WRITE           "CPLEX: CPXwriteLP failed"
#define ERR_CPLEX_OPT             "CPLEX: failed to optimize LP"
#define ERR_CPLEX_GET_SOLUTION    "CPLEX: failed to obtain solution"
#define ERR_CPLEX_FREE            "CPLEX: CPXfreeprob failed"
#define ERR_CPLEX_CLOSE           "CPLEX: CPXcloseCPLEX failed"

enum direction{north,east,south,west,unexplored};
enum v_type{real,bend,dissection,big};


void longest_paths(const GRAPH<int,int>&G,node_array<int>&l){
```

```
node_array<int>INDEG(G,0);node v;edge e;
stack<node>S;
forall_nodes(v,G){
INDEG[v]= indeg(v);
if(INDEG[v]==0)S.push(v);
}
while(!S.empty()){
v= S.pop();
forall_out_edges(e,v){
node w= target(e);
l[w]= Max(l[w],l[v]+G.inf(e));
if(--INDEG[w]==0)S.push(w);
}
}
}


int angle(const char c){
int result= 0;
switch(c){
case'0':result= 90;break;
case'1':result= 270;break;
default:error_handler(1,ERR_BAD_ANGLE);
}
return result;
}


bool Euler(const graph&G){
int n= 0;node v;forall_nodes(v,G)if(outdeg(v)!=0)++n;
int m= G.number_of_edges()/2;
int f= G.number_of_faces();
return(m==n+f-2);
}


class ortho_map:public planar_map{
node_map<node>v_in_G;
node_map<v_type>v_T;
edge_map<edge>e_in_G;
edge_map<edge>e_in_P;
edge_map<int>a;
edge_map<string>s;
edge_map<bool>inner;
edge_map<bool>cage;
edge_array<direction>dir;
edge_array<int>length;
node_array<int>x,y;

public:
edge next_level_edge(const node,const direction);
ortho_map(const graph&);
void print();
//bool check();
void init_maps(const edge,const int,const string,const bool,const bool);
node get_orig(const node v)const{return v_in_G[v];}
edge get_orig(const edge e)const{return e_in_G[e];}
```

```
direction get_dir(const edge e)const{return dir[e];}
edge get_copy(const edge e)const{return e_in_P[e];}
v_type get_type(const node v)const{return v_T[v];}
void set_inner(const edge e,const bool t){inner[e]= t;}
void set_cage(const edge e,const bool t){cage[e]= t;}
bool get_inner(const edge e)const{return inner[e];}
bool get_cage(const edge e)const{return cage[e];}
void set_type(const node v,const v_type t){v_T[v]= t;}
int get_a(const edge e)const{return a[e];}
void set_a(const edge e,const int angle){a[e]= angle;}
string get_s(const edge e)const{return s[e];}
void set_s(const edge e,const string s_new){s[e]= s_new;}
void set_s(const edge e,const int,const int,const bool);
int get_x(const node v)const{return x[v];}
int get_y(const node v)const{return y[v];}
void set_rev_s(const edge e,const int,const int,const bool);
void set_length(const edge e,const int l_new){length[e]= l_new;}
int get_length(const edge e)const{return length[e];}
edge split_map_edge(edge);
edge new_edge(edge,edge);
edge split_bend_edge(edge);
void PrintEdge(const edge);
void init_rest(){dir.init(*this,unexplored);
length.init(*this,0);
x.init(*this,-1);y.init(*this,-1);}


void ortho_map::assign_directions(edge e,direction d){
while(dir[e]==unexplored){
dir[e]= d;edge r= reversal(e);
if(dir[r]==unexplored){
if(inner[r])assign_directions(r,OPP(d));
else dir[r]= OPP(d);
}
switch(a[e]){
case 90:d= NEXT(d);break;
case 270:d= PREV(d);break;
case 360:d= OPP(d);break;
}
e= face_cycle_succ(e);
}
}

void determine_position(const node,const int x,const int
y,node_array<bool>&);
void norm_positions();
edge succ_corner_edge(const edge);
~ortho_map(){clear();}
LEDA_MEMORY(ortho_map)
};


edge ortho_map::next_level_edge(const node v,const direction d){
edge e;
switch(d){
case east: { forall_out_edges(e,v) if(dir[e]==north) return e; break; }
case west: { forall_in_edges(e,v)  if(dir[e]==north) return e; break; }
case north:{ forall_in_edges(e,v)  if(dir[e]==east)  return e; break; }
```

```
case south:{ forall_out_edges(e,v) if(dir[e]==east)  return e; break; }
default:break;
}
return NULL;
}



ortho_map::ortho_map(const graph&G):planar_map(G){
if(G.number_of_nodes()==0)error_handler(1,ERR_EMPTY_GRAPH);
if(!Is_Connected(G))error_handler(1,ERR_NOT_CONNECTED);
if(!Euler(G))error_handler(1,ERR_NO_PLANAR_MAP);
v_in_G.init(*this);e_in_G.init(*this);
e_in_P.init(G);


node v_P= first_node(),v_G= G.first_node();
while(v_P){
v_in_G[v_P]= v_G;
v_P= succ_node(v_P);
v_G= G.succ_node(v_G);
}
forall_nodes(v_P,*this){
v_G= v_in_G[v_P];
edge e_P= first_adj_edge(v_P),e_G= G.first_adj_edge(v_G);
while(e_P){
e_in_G[e_P]= e_G;e_in_P[e_G]= e_P;
e_G= adj_succ(e_G);e_P= adj_succ(e_P);
}
}


;
a.init(*this,90);s.init(*this,EPS);v_T.init(*this,real);
inner.init(*this,true);cage.init(*this,false);
}




edge ortho_map::split_map_edge(edge e){
edge n= planar_map::split_edge(e);
edge er= reversal(e),nr= reversal(n);
a[er]= a[nr];a[n]= a[e];
s[er]= EPS;s[n]= EPS;
inner[er]= inner[nr];cage[er]= cage[nr];
inner[n]= inner[e];cage[n]= cage[e];
e_in_G[n]= e_in_G[e];
e_in_G[er]= e_in_G[nr];
v_in_G[source(n)]= NULL;

return n;
}

edge ortho_map::split_bend_edge(edge e){
string s_e= s[e];int a_e= a[e];
bool inner_e= inner[e];bool cage_e= cage[e];
edge er= reversal(e);
string s_er= s[er];int a_er= a[er];
```

```
bool inner_er= inner[er];bool cage_er= cage[er];

edge n= split_map_edge(e);
er= reversal(e);edge nr= reversal(n);

a[e]= angle(s_e[s_e.length()-1]);a[er]= a_er;
a[n]= a_e;a[nr]= angle(s_er[0]);
s[e]= s_e.head(s_e.length()-1);s[er]= s_er.tail(s_er.length()-1);
s[n]= EPS;s[nr]= EPS;
inner[e]= inner[n]= inner_e;
cage[e]= cage[n]= cage_e;
inner[er]= inner[nr]= inner_er;
cage[er]= cage[nr]= cage_er;
v_T[source(n)]= bend;

return n;
}

edge ortho_map::new_edge(edge e1,edge e2){
edge n= planar_map::new_edge(e1,e2);
e_in_G[n]= NULL;e_in_G[reversal(n)]= NULL;
return n;
}


void ortho_map::print(){
face f;edge e;
forall_faces(f,(*this)){
if(!inner[first_face_edge(f)])cout<<"outer ";
if(cage[first_face_edge(f)])cout<<"cage ";
cout<<"face: "<<endl;
forall_face_edges(e,f){PrintEdge(e);newline;}
}
}

/*
bool ortho_map::check(){
bool result= true;return result;
face f;edge e;node v;
forall_faces(f,(*this)){
int rotation= 0;
forall_face_edges(e,f)rotation+= zeroes(s[e])-ones(s[e])+2-a[e]/90;
if(!inner[first_face_edge(f)])result= result&&(rotation==-4);
else result= result&&(rotation==4);
}
forall_nodes(v,(*this))if(outdeg(v)!=0){
int angle_sum= 0;
forall_in_edges(e,v)angle_sum+= a[e];
result= result&&(angle_sum==360);
}
return result;
}
*/

void ortho_map::set_s(const edge e,const int flow,const int flow_rev,
const bool bridge){
if(s[e]!=EPS)error_handler(1,ERR_BAD_STRING);
for(int i= 0;i<flow;i++)s[e]+= "0";
if(!bridge){
 for(int i= 0;i<flow_rev;i++)s[e]+= "1";
}
```

```
}

void ortho_map::set_rev_s(const edge e,const int flow,const int
flow_rev,
const bool bridge){
if(s[e]!=EPS)error_handler(1,ERR_BAD_STRING);
for(int i= 0;i<flow;i++)s[e]+= "1";
if(!bridge){
for(int i= 0;i<flow_rev;i++)s[e]= string('0')+s[e];
}
}

void ortho_map::PrintEdge(const edge e){
planar_map::print_edge(e);
cout<<"\t("<<s[e]<<" "<<a[e]<<" ["<<inner[e]<<cage[e]<<"])";
}

void ortho_map::init_maps(const edge e,const int a_new,const string
s_new,
const bool i_new,const bool c_new){
a[e]= a_new;s[e]= s_new;
inner[e]= i_new;cage[e]= c_new;
}


void ortho_map::determine_position(const node v,const int x_new,
const int y_new,node_array<bool>&seen){
if(seen[v])return;
edge e;x[v]= x_new;y[v]= y_new;
seen[v]= true;
forall_out_edges(e,v){
if(dir[e]==north)
determine_position(target(e),x_new+length[e],y_new,seen);
if(dir[e]==west)
determine_position(target(e),x_new,y_new+length[e],seen);
}
forall_in_edges(e,v){
if(dir[e]==north)
determine_position(source(e),x_new-length[e],y_new,seen);
if(dir[e]==west)
determine_position(source(e),x_new,y_new-length[e],seen);
}
}

void ortho_map::norm_positions(){
int xmin= 0,ymin= 0;node v;
forall_nodes(v,(*this))if(v_T[v]!=big){
xmin= Min(xmin,x[v]);
ymin= Min(ymin,y[v]);
}
forall_nodes(v,(*this)){
x[v]-= xmin;
y[v]-= ymin;
}
}

edge ortho_map::succ_corner_edge(const edge e){
edge e_c;
for(e_c= face_cycle_succ(e);a[e_c]==180;e_c= face_cycle_succ(e_c));
return e_c;
}
```

```
/*
bool Euler(const graph&);
int angle(const char);
int zeroes(const string&);
int ones(const string&);
void longest_paths(const GRAPH<int,int>&,node_array<int>&);
*/


/*
#include "common.h"
#include "ortho_map.h"
*/

#include <LEDA/stack.h>
#include <LEDA/array.h>
#include <LEDA/set.h>
#include <LEDA/integer_matrix.h>
#include <LEDA/graph_alg.h>

#ifdef CPLEX
extern"C"
#include<cplex.h>
#endif



typedef list<int>  intlist;
typedef list<node> nodelist;

int ORTHO_EMBEDDING(const graph&G,
                    node_array<int>&x_pos,
                    node_array<int>&y_pos,
                    edge_array<intlist>&x_bends,
                    edge_array<intlist>&y_bends, bool   )
{
ortho_map P(G);


node_map<edge>corr_cage_edge(P);
edge_array<nodelist>b_nodes(G);
edge_array<node>b_nodes_first(G,NULL);
edge_array<node>b_nodes_last(G,NULL);
list<node>all_nodes= P.all_nodes();
node v;edge e;face f;
forall(v,all_nodes)if(outdeg(v)>4){
P.set_type(v,big);
int d= outdeg(v),i= 0;
array<edge>out(d);edge e_cage;
```

```
forall_out_edges(e,v){
out[i++]= e;edge e_orig= P.get_orig(e);
edge e_split= P.split_map_edge(e);
node c_i= source(e_split);
P.set_type(c_i,bend);
b_nodes_first[e_orig]= c_i;
b_nodes_last[G.reversal(e_orig)]= c_i;
}



for(i= 0;i<d;i++){
e_cage= P.new_edge(SUCC(out[i]),REV(out[(i+1)%d]));
P.init_maps(e_cage,90,EPS,true,true);
edge r_cage= P.reversal(e_cage);
P.init_maps(r_cage,90,EPS,true,false);
}


corr_cage_edge[v]= e_cage;
forall_out_edges(e,v)P.join_faces(e);


}
//cout<<"cages created"<<endl;



//if(check)if(!Euler(P))error_handler(1,ERR_NO_PLANAR_MAP);


P.compute_faces();
face f_0;int f_0_deg= 0;
forall_faces(f,P)
if(!IS_CAGE(f)&&P.size(f)>f_0_deg){
f_0= f;f_0_deg= P.size(f_0);
}
forall_face_edges(e,f_0)P.set_inner(e,false);


;


graph N;
node s,t;
edge_array<int>cap,cost,l;
int z= 0;


list<node>V_hat;
list<node>F;
node_map<node>NtoV(N);
node_map<face>NtoF(N);
```

```
face_map<node>FtoN(P);


;


s= N.new_node();
t= N.new_node();
forall_nodes(v,P)if(outdeg(v)>0&&outdeg(v)<=3){
node n= N.new_node();
NtoV[n]= v;
V_hat.append(n);
}
forall_faces(f,P){
node n= N.new_node();
NtoF[n]= f;FtoN[f]= n;
F.append(n);
}


;


list<edge>A_s_v,A_s_f,A_v,A_v_cage,A_f,A_f_t;


forall_faces(f,P){
int size= P.size(f);
if(!IS_OUTER(f)&&size<=3)
A_s_f.append(N.new_edge(s,FtoN[f]));
if(IS_OUTER(f)||size>=5)A_f_t.append(N.new_edge(FtoN[f],t));
}
forall(v,V_hat)A_s_v.append(N.new_edge(s,v));


;


forall(v,V_hat){
set<face>F_adj;
forall_adj_faces(f,NtoV[v])F_adj.insert(f);
forall(f,F_adj)
if(IS_CAGE(f))A_v_cage.append(N.new_edge(v,FtoN[f]));
else A_v.append(N.new_edge(v,FtoN[f]));
}


;


#define MAX_BENDS_PER_EDGE INFINITY
edge_array<bool>marked(P,false);
edge_map<edge>partner(N),a_in_P(N);edge a1,a2;
forall_faces(f,P)
forall_face_edges(e,f)if(!marked[e]){
face g= P.face_of(REV(e));
if(f==g){
a1= N.new_edge(FtoN[f],FtoN[f]);
A_f.append(a1);
partner[a1]= a1;a_in_P[a1]= e;
}else{
```

```
a1= N.new_edge(FtoN[f],FtoN[g]);
a2= N.new_edge(FtoN[g],FtoN[f]);
A_f.append(a1);A_f.append(a2);
partner[a1]= a2;partner[a2]= a1;
a_in_P[a1]= e;a_in_P[a2]= e;
edge e_loop;
for(e_loop= e;
P.face_of(REV(e_loop))==g&&!marked[e_loop];
e_loop= SUCC(e_loop))
marked[e_loop]= marked[REV(e_loop)]= true;
for(e_loop= PRED(e);
P.face_of(REV(e_loop))==g&&!marked[e_loop];
e_loop= PRED(e_loop))
marked[e_loop]= marked[REV(e_loop)]= true;
}
}


;


;


cap.init(N,0);cost.init(N,0);int z_s= 0;edge a;
l.init(N,0);
forall(a,A_s_f)cap[a]= 4-P.size(NtoF[target(a)]);
forall(a,A_s_v)cap[a]= 4-outdeg(NtoV[target(a)]);
forall(a,A_v)cap[a]= 3;
forall(a,A_v_cage){cap[a]= 3;l[a]= 1;}
forall(a,A_f){
face g= NtoF[target(a)];face f= NtoF[source(a)];
cap[a]= IS_CAGE(g)?0:MAX_BENDS_PER_EDGE;
cost[a]= IS_CAGE(f)?0:1;
}
forall(a,A_f_t){
face f= NtoF[source(a)];
if(IS_OUTER(f))cap[a]= P.size(f)+4;
else cap[a]= P.size(f)-4;
}

forall_out_edges(a,s)z_s+= cap[a];
forall_in_edges(a,t)z+= cap[a];

A_v.conc(A_v_cage);

if(z!=z_s)error_handler(1,ERR_INVALID_NETWORK);


;
//cout<<"network constructed"<<endl;




edge_array<int>flow(N);
node_array<int>supply(N,0);
supply[s]= z;supply[t]= -z;
bool feasible= MIN_COST_FLOW(N,l,cap,cost,supply,flow);
```

```
if(!feasible)error_handler(1,ERR_NO_FEASIBLE_FLOW);
//cout<<"min-cost flow computed"<<endl;
```

```
forall(a,A_v){
node v= NtoV[source(a)];face f= NtoF[target(a)];
edge e_in;bool flag= false;
forall_in_edges(e_in,v)
if(P.face_of(e_in)==f&&!flag){
P.set_a(e_in,(flow[a]+1)*90);
flag= true;
}
}
```

```
marked.init(N,false);int no_of_bends= 0;
forall(a,A_f)if(!marked[a]){
edge a_rev= partner[a];
marked[a]= true;marked[a_rev]= true;
e= a_in_P[a];
bool bridge= (a==a_rev);
P.set_s(e,flow[a],flow[a_rev],bridge);
P.set_rev_s(REV(e),flow[a],flow[a_rev],bridge);
no_of_bends+= (flow[a]+flow[a_rev]);
}
```

```
marked.init(P,false);
list<edge>all_edges= P.all_edges();
forall(e,all_edges)if(!marked[e]){
marked[e]= true;marked[REV(e)]= true;
edge e_orig= P.get_orig(e);
while(P.get_s(e)!=EPS){
edge e_split= P.split_bend_edge(e);
if(e_orig){
b_nodes[e_orig].push(source(e_split));
b_nodes[G.reversal(e_orig)].append(source(e_split));
}
}
if(e_orig){
if(b_nodes_first[e_orig]){
b_nodes[e_orig].push(b_nodes_first[e_orig]);
b_nodes[G.reversal(e_orig)].append(b_nodes_first[e_orig]);
}
if(b_nodes_last[e_orig]){
b_nodes[e_orig].append(b_nodes_last[e_orig]);
b_nodes[G.reversal(e_orig)].push(b_nodes_last[e_orig]);
}
}
```

```
}

//cout<<"orthogonal representation constructed"<<endl;
//if(check)if(!P.check())error_handler(1,ERR_NO_ORTHO_REP);
//cout<<"no. of bends in 4-graph: "<<no_of_bends<<endl;

list<face>all_faces;

forall_faces(f,P)if(IS_OUTER(f))all_faces.push(f);
else{
if(IS_CAGE(f)){
int pred_angle= P.get_a(PRED(P.first_face_edge(f)));
forall_face_edges(e,f){
int act_angle= P.get_a(e);
if(pred_angle==90&&act_angle==90){
edge e_split= P.split_map_edge(e);
P.set_a(e,180);P.set_a(REV(e_split),180);
P.set_type(source(e_split),dissection);
}
pred_angle= P.get_a(e);
}
}
all_faces.append(f);
}

forall(f,all_faces){

stack<edge>S;
int size= 0;
forall_face_edges(e,f)size+= abs(2-P.get_a(e)/90);
e= P.succ_corner_edge(P.first_face_edge(f));int state= 0;
while(size>4){
if(state==0&&!S.empty()){
e= P.succ_corner_edge(S.top());
state= 1;
}
int angle= P.get_a(e);
switch(angle){
case 90:if(state==2)state= 3;
if(state==1)state= 2;
break;
case 270:
case 360:if(state==2&&IS_OUTER(f))state= 4;
else{
S.push(e);state= 1;
if(angle==360)S.push(e);
}
break;
}
if(state==3){
```

```
edge e1= S.pop();
edge e2= P.succ_corner_edge(e1);
edge e3= P.succ_corner_edge(e2);
edge e4= P.succ_corner_edge(e3);int a4= P.get_a(e4);
edge e5= P.split_map_edge(e4);
P.set_type(source(e5),dissection);
P.set_a(e1,P.get_a(e1)-90);
P.set_a(e5,a4);P.set_a(REV(e5),180);
P.set_a(e4,90);
edge e6= P.new_edge(P.face_cycle_succ(e1),e5);
P.init_maps(e6,90,EPS,P.get_inner(e1),false);
P.init_maps(REV(e6),90,EPS,true,false);
P.set_inner(e2,true);P.set_inner(e3,true);P.set_inner(e4,true);
size-= 2;state= 0;e= e6;


}
if(state==4){

edge e1= S.pop();
edge e2= P.succ_corner_edge(e1);
edge e3= P.succ_corner_edge(e2);
edge e4= P.new_edge(P.face_cycle_succ(e1),P.face_cycle_succ(e3));
P.init_maps(e4,P.get_a(e3)-90,"1",false,false);
P.init_maps(REV(e4),90,"0",true,false);
edge e5= P.split_bend_edge(e4);
P.set_a(e1,P.get_a(e1)-90);
P.set_inner(e2,true);
P.init_maps(e3,90,EPS,true,false);
P.set_type(source(e5),dissection);
S.push(e1);
size-= 2;state= 0;


}
e= P.succ_corner_edge(e);
}


}
//if(check&&!P.check())error_handler(1,ERR_NO_ORTHO_REP);


P.init_rest();
P.assign_directions(P.first_edge(),north);







#ifdef CPLEX
```

```
int n= 0;int m= 0;
node_array<int>v_num(P);edge_array<int>e_num(P,-1);
forall_nodes(v,P)v_num[v]= n++;
forall_edges(e,P)if(P.get_dir(e)==north||P.get_dir(e)==west)
e_num[e]= m++;
int basic_rows= 2*m;
int rows= basic_rows;
int cols= 2*n;
int basic_nonzeroes= 2*basic_rows;
int nonzeroes= basic_nonzeroes;
double*obj= new double[cols];
double*rhs= new double[rows];
char*sense= new char[rows];
int*matbeg= new int[cols];
int*matcnt= new int[cols];
int*matind= new int[nonzeroes];
double*matval= new double[nonzeroes];
double*lb= new double[cols];
double*ub= new double[cols];

CPXENVptr env= NULL;
CPXLPptr lp= NULL;

int status;
```

```
for(int j= 0;j<cols;j++){
obj[j]= 0.0;
matbeg[j]= 0;matcnt[j]= 0;
lb[j]= 0.0;ub[j]= INFBOUND;
}
for(int k= 0;k<basic_nonzeroes;k++){
matind[k]= 0;matval[k]= 0.0;
}
```

```
#define X(v) (v_num[v])
#define Y(v) (n + v_num[v])
forall_edges(e,P){
node s= source(e),t= target(e);
switch(P.get_dir(e)){
case north:
obj[v_num[s]]-= 1.0;
obj[v_num[t]]+= 1.0;
break;
case west:
obj[v_num[s]+n]-= 1.0;
obj[v_num[t]+n]+= 1.0;
break;
default:break;
}
}
```

```
int nonzero_cnt= 0;
forall_nodes(v,P){
int act_col= X(v);
matbeg[act_col]= nonzero_cnt;
forall_inout_edges(e,v){
bool out_edge= (v==source(e));int act_row;
switch(P.get_dir(e)){
case north:
act_row= 2*e_num[e];
matcnt[act_col]++;
if(out_edge)matval[nonzero_cnt]= 1.0;
else matval[nonzero_cnt]= -1.0;
matind[nonzero_cnt]= act_row;
sense[act_row]= 'L';rhs[act_row]= -1.0;
++nonzero_cnt;
break;
case west:
act_row= 2*e_num[e]+1;
matcnt[act_col]++;
if(out_edge)matval[nonzero_cnt]= 1.0;
else matval[nonzero_cnt]= -1.0;
matind[nonzero_cnt]= act_row;
sense[act_row]= 'E';rhs[act_row]= 0.0;
++nonzero_cnt;
break;
default:break;
}
}
}
forall_nodes(v,P){
int act_col= Y(v);
matbeg[act_col]= nonzero_cnt;
forall_inout_edges(e,v){
bool out_edge= (v==source(e));int act_row;
switch(P.get_dir(e)){
case west:
act_row= 2*e_num[e];
matcnt[act_col]++;
if(out_edge)matval[nonzero_cnt]= 1.0;
else matval[nonzero_cnt]= -1.0;
matind[nonzero_cnt]= act_row;
sense[act_row]= 'L';rhs[act_row]= -1.0;
++nonzero_cnt;
break;
case north:
act_row= 2*e_num[e]+1;
matcnt[act_col]++;
if(out_edge)matval[nonzero_cnt]= 1.0;
else matval[nonzero_cnt]= -1.0;
matind[nonzero_cnt]= act_row;
sense[act_row]= 'E';rhs[act_row]= 0.0;
++nonzero_cnt;
break;
default:break;
}
}
```

```
}
env= CPXopenCPLEX(&status);
if(env==NULL)error_handler(1,ERR_OPEN_CPLEX_ENV);

lp= CPXloadlp(env,"find_coords",cols,basic_rows,CPX_MIN,obj,rhs,
sense,matbeg,matcnt,matind,
matval,lb,ub,NULL,cols,rows,nonzeroes);
if(lp==NULL)error_handler(1,ERR_LOAD_LP);




int solstat;
double objval;
double*sol= new double[cols];
double*pi= new double[rows];
double*slack= new double[rows];
double*dj= new double[cols];

status= CPXoptimize(env,lp);
if(status){
CPXcloseCPLEX(&env);
error_handler(1,ERR_CPLEX_OPT);
}

status= CPXsolution(env,lp,&solstat,&objval,sol,pi,slack,dj);
if(status)error_handler(1,ERR_CPLEX_GET_SOLUTION);
int max_x= 0,max_y= 0;
forall_nodes(v,P)if(P.get_type(v)==real){
max_x= Max(max_x,(x_pos[P.get_orig(v)]= (int)sol[X(v)]));
max_y= Max(max_y,(y_pos[P.get_orig(v)]= (int)sol[Y(v)]));
}

if(env)status= CPXfreeprob(env,&lp);
if(status)error_handler(1,ERR_CPLEX_FREE);
status= CPXcloseCPLEX(&env);
if(status)error_handler(1,ERR_CPLEX_CLOSE);




#else




graph N_h,N_v;
face_map<node>FtoN_h(P),FtoN_v(P);
edge_map<edge>EtoA(P);


node s_h= N_h.new_node(),t_h= N_h.new_node(),s_v= N_v.new_node(),
t_v= N_v.new_node();

forall_faces(f,P){
if(!IS_OUTER(f)){
FtoN_h[f]= N_h.new_node();
```

```
FtoN_v[f]= N_v.new_node();
}
}
```

```
forall_faces(f,P)forall_face_edges(e,f){
face g= P.face_of(REV(e));
bool out_f= IS_OUTER(f),out_g= IS_OUTER(g);
switch(P.get_dir(e)){
case north:
if(out_f&&!out_g)EtoA[e]= N_h.new_edge(FtoN_h[g],t_h);
if(out_g&&!out_f)EtoA[e]= N_h.new_edge(s_h,FtoN_h[f]);
if(out_f&&out_g)EtoA[e]= N_h.new_edge(s_h,t_h);
if(!out_f&&!out_g)EtoA[e]=
N_h.new_edge(FtoN_h[g],FtoN_h[f]);
break;
case west:
if(out_f&&!out_g)EtoA[e]= N_v.new_edge(FtoN_v[g],t_v);
if(out_g&&!out_f)EtoA[e]= N_v.new_edge(s_v,FtoN_v[f]);
if(out_f&&out_g)EtoA[e]= N_v.new_edge(s_v,t_v);
if(!out_f&&!out_g)EtoA[e]=
N_v.new_edge(FtoN_v[g],FtoN_v[f]);
break;
default:break;
}
}
edge e_h= N_h.new_edge(s_h,t_h);
edge e_v= N_v.new_edge(s_v,t_v);
```

```
edge_array<int>cap_h(N_h,INFINITY),cap_v(N_v,INFINITY);
edge_array<int>cost_h(N_h,1),cost_v(N_v,1);
edge_array<int>l_h(N_h,1),l_v(N_v,1);
edge_array<int>flow_h(N_h,0),flow_v(N_v,0);
node_array<int>b_h(N_h,0),b_v(N_v,0);
forall_nodes(v,N_h)
b_h[s_h]+= abs(outdeg(v)-indeg(v));
b_h[s_h]= b_h[s_h]/2+1;
b_h[t_h]= -b_h[s_h];
forall_nodes(v,N_v)
b_v[s_v]+= abs(outdeg(v)-indeg(v));
b_v[s_v]= b_v[s_v]/2+1;
b_v[t_v]= -b_v[s_v];
cost_h[e_h]= 0;cost_v[e_v]= 0;
l_h[e_h]= 0;l_v[e_v]= 0;
```

```
feasible= MIN_COST_FLOW(N_h,l_h,cap_h,cost_h,b_h,flow_h);
if(!feasible)error_handler(1,ERR_NO_FEASIBLE_FLOW);
feasible= MIN_COST_FLOW(N_v,l_v,cap_v,cost_v,b_v,flow_v);
if(!feasible)error_handler(1,ERR_NO_FEASIBLE_FLOW);
```

```
forall_edges(e,P){
switch(P.get_dir(e)){
case north:
P.set_length(e,flow_h[EtoA[e]]);
P.set_length(REV(e),flow_h[EtoA[e]]);
break;
case west:
P.set_length(e,flow_v[EtoA[e]]);
P.set_length(REV(e),flow_v[EtoA[e]]);
break;
default:break;
}
}




//for(v= P.choose_node();P.get_type(v)!=real;v= P.succ_node(v));

forall_nodes(v,P)
    if (P.get_type(v) == real) break;

x_pos.init(G);y_pos.init(G);node_array<bool>seen(P,false);
P.determine_position(v,0,0,seen);
P.norm_positions();
int max_x= 0,max_y= 0;
forall_nodes(v,P)if(P.get_type(v)==real){
int x = P.get_x(v);
int y = P.get_y(v);
x_pos[P.get_orig(v)]=x;
y_pos[P.get_orig(v)]=y;
max_x= Max(max_x,x);
max_y= Max(max_y,y);
}


//cout<<"coordinates computed by network method"<<endl;


#endif


forall_nodes(v,P)if(P.get_type(v)==big){
int x_big,y_big;
list<int>lx,ly;
face f_cage= P.face_of(corr_cage_edge[v]);
forall_face_edges(e,f_cage){
if(P.get_type(source(e))!=dissection){
int x= P.get_x(source(e)),y= P.get_y(source(e));
lx.append(x);ly.append(y);
}
}
lx.sort();ly.sort();list_item it;
x_big= (lx.head()+lx.tail())/2;
```

```
y_big= (ly.head()+ly.tail())/2;

forall_items(it,lx)
  if(lx[it]!=lx.head()&&lx[it]!=lx.tail()
     &&lx[it]==lx[lx.cyclic_succ(it)]) x_big= lx[it];

forall_items(it,ly)
   if(ly[it]!=ly.head()&&ly[it]!=ly.tail()
      &&ly[it]==ly[ly.cyclic_succ(it)]) y_big= ly[it];

x_pos[P.get_orig(v)]= x_big;
y_pos[P.get_orig(v)]= y_big;
}

x_bends.init(G);y_bends.init(G);
forall_edges(e,G)
forall(v,b_nodes[e]){
x_bends[e].append(P.get_x(v));
y_bends[e].append(P.get_y(v));
}

//cout<<"cages resolved"<<endl<<endl;




return Max(max_x,max_y);
}
```

```
/*******************************************************************************
********
+
+  LEDA 3.5.1
+
+  _spring.c
+
+  This file is part of the LEDA research version (LEDA-R) that can be
+  used free of charge in academic research and teaching. Any commercial
+  use of this software requires a license which is distributed by the
+  LEDA Software GmbH, Postfach 151101, 66041 Saarbruecken, FRG
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+  Im Stadtwald, 66123 Saarbruecken, Germany
+  All rights reserved.
+
*******************************************************************************
*******/
#include <LEDA/graph_alg.h>

#include <math.h>
#include <LEDA/array2.h>


#define FREPULSE(d)  ((k2 > d) ? kk/d : 0)

static float log_2(int x)
{ float l = 0;
  while (x)
  { l++;
    x >>= 1;
   }
  return l/2;
}


void SPRING_EMBEDDING(const graph& G, node_array<double>& xpos,
                                      node_array<double>& ypos,
                                      double xleft, double xright,
                                      double ybottom, double ytop,
                                      int iterations)
{ list<node> L;
  SPRING_EMBEDDING(G,L,xpos,ypos,xleft,xright,ybottom,ytop,iterations);
}


void SPRING_EMBEDDING(const graph& G, const list<node>& fixed_nodes,
                                      node_array<double>& xpos,
                                      node_array<double>& ypos,
                                      double xleft, double xright,
                                      double ybottom, double ytop,
                                      int iterations)
{

  if (xleft >= xright || ybottom >= ytop)
      error_handler(1,"SPRING_EMBDDING: illegal bounds.");

  node_array<list_item> lit(G);
  node_array<bool>  fixed(G,false);
```

```
node u,v;
edge e;

forall(v,fixed_nodes) fixed[v] = true;

int c_f = 1;

double width  = xright - xleft;
double height = ytop - ybottom;

double tx_null = width/50;
double ty_null = height/50;
double tx = tx_null;
double ty = ty_null;

double k = sqrt(width*height / G.number_of_nodes()) / 2;
double k2 = 2*k;
double kk = k*k;

int ki = int(k);

if (ki == 0) ki = 1;

//build  matrix of node lists

int xA = int(width / ki + 1);
int yA = int(height / ki + 1);

array2<list<node> > A(-1,xA,-1,yA);

forall_nodes(v,G)
{ int i = int((xpos[v] - xleft)   / ki);
  int j = int((ypos[v] - ybottom) / ki);
  if (i >= xA || i < 0) error_handler(1,"spring: node out of range");
  if (j >= yA || j < 0) error_handler(1,"spring: node out of range");
  lit[v] = A(i,j).push(v);
}


while (c_f < iterations)
{
  node_array<double>  xdisp(G,0);
  node_array<double>  ydisp(G,0);

 // repulsive forces

 forall_nodes(v,G)
 { int i = int((xpos[v] - xleft)   / ki);
   int j = int((ypos[v] - ybottom) / ki);

   double xv = xpos[v];
   double yv = ypos[v];

   for(int m = -1; m <= 1; m++)
    for(int n = -1; n <= 1; n++)
     forall(u,A(i+m,j+n))
     { if(u == v) continue;
       double xdist = xv - xpos[u];
       double ydist = yv - ypos[u];
       double dist = sqrt(xdist * xdist + ydist * ydist);
       if (dist < 1e-3) dist = 1e-3;
```

```
      xdisp[v] += FREPULSE(dist) * xdist / dist;
      ydisp[v] += FREPULSE(dist) * ydist / dist;
     }
   xdisp[v] *=  (double(rand_int(750,1250))/1000.0);
   ydisp[v] *=  (double(rand_int(750,1250))/1000.0);
  }


// attractive forces

forall_edges(e,G)
{ node u = G.source(e);
  node v = G.target(e);
  double xdist=xpos[v]-xpos[u];
  double ydist=ypos[v]-ypos[u];
  double dist=sqrt(xdist*xdist+ydist*ydist);

  float f = (G.degree(u)+G.degree(v))/6.0;

  dist /= f;

  xdisp[v]-=xdist*dist/k;
  ydisp[v]-=ydist*dist/k;
  xdisp[u]+=xdist*dist/k;
  ydisp[u]+=ydist*dist/k;
 }


// preventions

forall_nodes(v,G)
{
  if (fixed[v]) continue;

  int i0 = int((xpos[v] - xleft)/ki);
  int j0 = int((ypos[v] - ybottom)/ki);

  double xd= xdisp[v];
  double yd= ydisp[v];
  double dist = sqrt(xd*xd+yd*yd);

  if (dist < 1) dist = 1;

  xd = tx*xd/dist;
  yd = ty*yd/dist;

  double xp = xpos[v] + xd;
  double yp = ypos[v] + yd;

  int i = i0;
  int j = j0;

  if (xp > xleft && xp < xright)
  { xpos[v] = xp;
    i = int((xp - xleft)/ki);
   }

  if (yp > ybottom && yp < ytop)
  { ypos[v] = yp;
    j = int((yp - ybottom)/ki);
```

```
        }

      if (i != i0 || j != j0)
      { if (lit[v] == nil) error_handler(1,"delete nil item");
        A(i0,j0).del_item(lit[v]);
        lit[v] = A(i,j).push(v);
       }

    }

   tx = tx_null / log_2(c_f);
   ty = ty_null / log_2(c_f);

   c_f++;
  }

}
```

```
/***********************************************************************
********
+
+  LEDA 3.5.1
+
+  _sugiyama.c
+
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+
************************************************************************
*******/
//----------------------------------------------------------------------
--
// SUGIYAMA EMBEDDING
//
// D. Ambras (1996/97)
//----------------------------------------------------------------------
--


#include <stdio.h>
#include <LEDA/array.h>
#include <LEDA/p_queue.h>
#include <LEDA/stream.h>
#include <LEDA/graph.h>
#include <LEDA/graph_alg.h>

#ifdef _DRAW_SUGI
 #include <LEDA/panel.h>
#endif


typedef int  bitarray;

#define SORT_LOWER 1
#define SORT_UPPER 2
#define SORT_BOTH  3
#define PERMUTE    4
#define IMPROVE    8

#define HIGH    1
#define LOW     0
#define UP      1
#define DOWN    0

#ifdef _DRAW_SUGI
window  W;
#endif
double  aspect_ratio=3;
int     ps_count=1;
int     perm_max=10, sort_max=6;
int     max_level;
bool    do_debug=true;
```

```
void write_to_ps(const graph &G, array<list<node> > &Level,
node_array<int>
                   &x_coord, node_array<int> &nlabel, int width, int
height,
                   char *headline, file_ostream &out)
{
 int    x_off, y_off, x_gap, y_gap, radius, i;
  x_off  = y_off= x_gap= 20;
  y_gap  = int(x_gap * aspect_ratio + 0.5);
  radius = 3;

 node   v, s, t;
 edge   e;

 out << "%!PS\n";
 out << "%%Creator: SUGIYAMA_EMBEDDING v1.0\n";
 out << "%%Pages: 1\n";
 out << "%%PageOrder: Ascend\n";
 out << "%%BoundingBox: " << 0 << " " << 0 << " ";
 out << x_gap*width + 2*x_off << " " << y_gap*height + 2*y_off << "\n";
 out << "%%EndComments\n\n%%Page: 1 1\n\n";

 out << "% " << headline << endl << endl;



 out << "% drawing the nodes\n\n";
 i=-1;
 while ((++i) <= max_level)
  forall(v, Level[i]) if (nlabel[v] != 0)
  { out << "newpath ";
    out << x_gap *x_coord[v] +x_off << " " << y_gap *i +y_off;
    out << " " << radius << " 0 360 arc fill\n";
  }

 out << "\n% drawing the edges\n\nnewpath\n";
 i=0;

 while ((++i) <= max_level)                              // drawing the
edges
  forall(v, Level[i-1])
    forall_out_edges(e, v)
    { s= G.source(e);  t= G.target(e);
      out << x_gap *x_coord[s] +x_off << " " << y_gap*(i-1) +y_off
          << " moveto  ";
      out << x_gap *x_coord[t] +x_off << " " << y_gap*i +y_off
          << " lineto\n";
     }

 out << "stroke\nshowpage\n\n%%EOF" << endl << flush;
}
```

```
#ifdef _DRAW_SUGI

void user_exit(void)
{
 cout << "Aborted." << endl << flush;
 exit(1);
}



bool draw_hierarchy(const graph &G, array<list<node> > &Level,
                     node_array<int> &x_coord, node_array<int> &nlabel,
                     char *headline, const bool &draw_virtual_nodes)
{
 int    i, x_min=100, x_max=-100, xv, b=NO_BUTTON;
 int    width=0, height;
 double W_size;
 color  bkg_color=white, node_color, edge_color=blue;
 color  rnode_color=green, vnode_color=white;
 node   v, w;
 edge   e;
 char   filename[200];

 forall_nodes(v, G)
 { i=x_coord[v];
   if (x_min > i) x_min= i;
   if (x_max < i) x_max= i;
 }

 width= x_max -x_min +1;
 height=max_level + 1;

 W_size=(width > height*aspect_ratio ? width: height*aspect_ratio);
 W.init(-1, W_size, -1);
 W.clear(bkg_color);  W.set_frame_label(headline);



#ifdef _DEBUG_SUGI
  if (do_debug)
  { W.message("writing graph to disk ...");
    sprintf(filename, "figure%d.ps", ps_count);
    file_ostream  ps_out(filename);
    write_to_ps(G, Level, x_coord, nlabel, width,
                height, filename, ps_out);
    ps_count++;
  }
#elif _DEBUG2_SUGI
  if (do_debug)
  { W.message("writing graph to disk ...");
    sprintf(filename, "figure%d.ps", ps_count);
    file_ostream  ps_out(filename);
    write_to_ps(G, Level, x_coord, nlabel, width,
                height, filename, ps_out);
    ps_count++;
  }
```

```
#endif

 i=0;  forall(v, Level[i])
 W.draw_int_node(x_coord[v]-x_min, i*aspect_ratio, nlabel[v],
rnode_color);

 do
 { if (i == max_level)                          // no more levels
   { W.message(
     "press left mouse button to proceed, other button to abort");
     while (b == NO_BUTTON) b= W.get_button();
     W.del_messages();
     if (b==MOUSE_BUTTON(1))
     { W.message("continue calculations, please wait ...");
       return true;
     }
     return false;
   }

   forall(v, Level[i])                                  // drawing the
edges
   { xv=x_coord[v]-x_min;
     forall_out_edges(e, v)
      if (draw_virtual_nodes || (nlabel[v] > 0 && nlabel[G.target(e)] >
0) )
       W.draw_edge(xv, i*aspect_ratio, x_coord[G.target(e)]-x_min,
                   (i+1)*aspect_ratio, edge_color);
      else
       W.draw_segment(xv, i*aspect_ratio, x_coord[G.target(e)]-x_min,
                      (i+1)*aspect_ratio, edge_color);
   }

   forall(v, Level[i+1])                                // drawing the
nodes
   { if (nlabel[v]==0) node_color=vnode_color;
      else node_color=rnode_color;
     if (draw_virtual_nodes || nlabel[v] > 0)
      W.draw_int_node(x_coord[v]-x_min, (i+1)*aspect_ratio,
                      nlabel[v], node_color);
   }
   i++;
 } while (0<1);
}




#endif


bool slide_node(const graph &G, const node &v, const int &priority,
         const int &best_pos, node_array<int> &x_coord, node_array<int>
&x_prio,
         array<bool> &x_set, array<node> &x_owner)
{
 int    cur_pos=x_coord[v], N=G.number_of_nodes();
```

```
 while (cur_pos < best_pos)
 { if (cur_pos > N-1) return false;

   if (x_set[cur_pos+1])
   { if (x_prio[ x_owner[cur_pos+1]] > priority)
       return false;

     if ( !slide_node(G, x_owner[cur_pos+1],
                        priority, cur_pos+2,
                        x_coord, x_prio,
                        x_set, x_owner))  return false;
                                          // owner was move-able, but
others not
   }

   x_set[cur_pos++]=false;
   x_set[cur_pos]=true;                   // move node one step
   x_owner[cur_pos]=v;
   x_coord[v]=cur_pos;
 }



 while (cur_pos > best_pos)
 { if (cur_pos < -N+1) return false;

   if (x_set[cur_pos-1])
   { if (x_prio[ x_owner[cur_pos-1]] >= priority)
       return false;

     if ( !slide_node(G, x_owner[cur_pos-1],
                        priority, cur_pos-2,
                        x_coord, x_prio,
                        x_set, x_owner))  return false;
   }
   x_set[cur_pos--]=false;
   x_set[cur_pos]=true;
   x_owner[cur_pos]=v;
   x_coord[v]=cur_pos;
 }


 return true;                             // successful move
}



bool two_level(const graph &G, array<list<node> > &Level, const int
&upper,
             node_array<int> &x_coord, node_array<int> &x_prio,
             const bitarray &what_to_do)
{
 bool           changes=false;
 int            lower=upper+1, N=G.number_of_nodes();
```

```
int             x, count, pcount, hprio_count;
node            nu, nl;
node            u, v;
edge            e;
double          bary, old_bary, hprio_bary;

list<node>              equal_bary;
p_queue<double, node>   Su, Sl;
pq_item                 pit;

array<bool>             x_set(-N, N);
array<node>             x_owner(-N, N);
node_array<int>         p_bary(G);



if (what_to_do & SORT_UPPER)
{ forall(nu, Level[upper])
  { bary=0;
    hprio_count=0;
    hprio_bary=0;

    forall_out_edges(e, nu)
    { x=x_coord[ G.target(e) ];  bary+=x;
      if (x_prio[ G.target(e) ] == N)            // a long edge
      { hprio_count++;
        hprio_bary+=x;
      }
    }

    if (count=G.outdeg(nu))  bary =bary/count;
      else bary=x_coord[nu];                     // no in- edges

    if (what_to_do & IMPROVE)
    { Su.insert(-x_prio[nu], nu);                // sort by priority
      p_bary[nu]=(int)(bary+0.5);
      if (hprio_count)
        p_bary[nu]=(int)(hprio_bary/ hprio_count +0.5);
                                                 // we ignore short edges
    }
    else  Su.insert(bary, nu);
  }

  if (what_to_do & IMPROVE)
  { for(x=-N; x<= N; x++)   x_set[x]=false;
    forall(v, Level[upper])
    { x_owner[ x_coord[v]]=v;
      x_set[   x_coord[v]]=true;
    }
  }


  count=0;  old_bary=-1;  pcount=-2;

  while(Su.size())
  { pit=Su.find_min();
    v=Su.inf(pit);
    bary=Su.prio(pit);
    Su.del_item(pit);
```

```
    if (what_to_do & IMPROVE)                          // set real
x_coordinates
      slide_node(G, v,
                 x_prio[v], p_bary[v],
                 x_coord, x_prio,
                 x_set, x_owner);

    else if (x_coord[v] != count)                      // set consecutive
x_coordinates
    { changes=true;
      x_coord[v] = count;
    }

    if (what_to_do & PERMUTE)                          // we shall permute
     if (bary==old_bary)
     { equal_bary.append(u);
       pcount=count;
     }
     else
     { if (pcount == count-1) equal_bary.append(u);
       while (!equal_bary.empty())
       { changes=true;
         x_coord[equal_bary.pop()]= pcount--;
       }
     }
    count++;
    old_bary=bary;
    u=v;
  }
  if (pcount == count-1) equal_bary.append(u);

  while (!equal_bary.empty())                          // flush equal_bary
  { changes=true;
    x_coord[equal_bary.pop()]= pcount--;
  }
 }


 if (what_to_do & SORT_LOWER)
 { forall(nl, Level[lower])
   { bary=0;
     hprio_count=0;
     hprio_bary=0;

     forall_in_edges(e, nl)
     { x=x_coord[ G.source(e) ];  bary+=x;
       if (x_prio[ G.source(e) ] == N)                 // a long edge
       { hprio_count++;
         hprio_bary+=x;
       }
     }
     if (count=G.indeg(nl))  bary =bary/count;
      else bary=x_coord[nl];

     if (what_to_do & IMPROVE)                         // set real
x_coordinates
     { Sl.insert(-x_prio[nl], nl);
       p_bary[nl]=(int)(bary +0.5);
       if (hprio_count)
```

```
        p_bary[nl]=(int)(hprio_bary/ hprio_count +0.5);
                                                    // ignore short edges
      }
      else  Sl.insert(bary, nl);
    }

    if (what_to_do & IMPROVE)
    { for(x=-N; x<= N; x++)   x_set[x]=false;
      forall(v, Level[lower])
      { x_owner[ x_coord[v]]= v;
        x_set[   x_coord[v]]= true;
      }
    }


    count=0;  old_bary=-1;  pcount=-2;

    while(Sl.size())
    { pit=Sl.find_min();
      v=Sl.inf(pit);
      bary=Sl.prio(pit);
      Sl.del_item(pit);

      if (what_to_do & IMPROVE)
        slide_node(G, v,
                    x_prio[v], p_bary[v],
                    x_coord, x_prio,
                    x_set, x_owner);

      else if (x_coord[v] != count)
      { changes=true;
        x_coord[v] = count;
      }
      if (what_to_do & PERMUTE)
       if (bary==old_bary)
       { equal_bary.append(u);
         pcount=count;
       }
       else
       { if (pcount == count-1) equal_bary.append(u);
         while (!equal_bary.empty())
         { changes=true;
           x_coord[equal_bary.pop()]=pcount--;
         }
       }
      count++;
      old_bary=bary;
      u=v;
    }
    if (pcount == count-1) equal_bary.append(u);

    while (!equal_bary.empty())                 // flush equal_bary
    { changes=true;
      x_coord[equal_bary.pop()]=pcount--;
    }
  }


#ifdef _DEBUG2_SUGI
```

```
 char    headline[200], dir[10], text_p[10], text_i[10];

 if (( upper > 10) && do_debug)
 { if (what_to_do & SORT_LOWER) sprintf(dir, "[down]");
     else sprintf(dir, "[up]");
// ( supposed SORT_BOTH is not selected )

   if (what_to_do & PERMUTE) sprintf(text_p, " + permute");
     else sprintf(text_p, " ");

   if (what_to_do & IMPROVE) sprintf(text_i, " + improve");
     else sprintf(text_i, " ");

   sprintf(headline, "after two_level for u-level %d, sort %swards%s%s",
         upper, dir, text_p, text_i);

   if (!draw_hierarchy(G, Level, x_coord, x_coord, headline, true))
user_exit();
 }
#endif


 return changes;
}



list<edge> sort_edges(const graph &G, array<list<node> > &Level,
                        const int &column, const int &height,
                        node_array<int> &x_coord, list<edge> &edges)
{
 int          i=0;
 node         v;
 edge         e;
 list<edge>   result;

 array< list<edge> >    nlist( Level[column].size() );

 forall(e, edges)
 { if (height == LOW)  v=G.target(e);
    else v=G.source(e);
   nlist[ x_coord[v] ].append(e);
 }

 while (i < Level[column].size() )
  result.conc(nlist[i++]);

 return result;
}



static bool cross(const graph &G, node_array<int> &x_coord,
                   edge_array<int> &current_pos, const edge &e, const
edge &f)
{
 int   xu1, xu2, xl1, xl2;

 xu1=current_pos[e];
 xu2=current_pos[f];
 xl1=x_coord[ G.target(e) ];
```

```
 xl2=x_coord[ G.target(f) ];

 return ( xu1 < xu2 && xl1 > xl2) || ( xu1 > xu2 && xl1 < xl2 );

}



int number_of_crossings(const graph &G, array<list<node> > &Level,
                         const int &upper, node_array<int> &x_coord)
{
 int            lower=upper+1, result=0, i;
 node           vu;
 edge           e, f, g, h;
 list<edge>     edges, work_list;
 list_item      lit;

 forall(vu, Level[upper])
  forall_adj_edges(e, vu) edges.append(e);

 edges= sort_edges(G, Level, lower, LOW , x_coord, edges);
 edges= sort_edges(G, Level, upper, HIGH, x_coord, edges);



 array<edge>                current_order(edges.size() );
 edge_array<int>            current_pos(G);
 edge_array<list_item>      worklist_it(G, nil);

 i=0;
 forall(e, edges)
 { current_order[i]=e;
   current_pos[e]=i++;
 }

 for (i=0; i < edges.size()-1; i++)
 { e=current_order[i];
   f=current_order[i+1];
   if ( cross(G, x_coord, current_pos, e, f) )
     worklist_it[e] = work_list.append(e);
 }



 while (!work_list.empty() )
 { e=work_list.pop();
   worklist_it[e]= nil;
   i=current_pos[e];
   result++;

   if (i < edges.size()-1)
   { f=current_order[i+1];
     current_order[i]=f;
     current_order[i+1]=e;
     current_pos[e]++;
     current_pos[f]--;

     if (lit=worklist_it[f])
```

```
      { work_list.del_item(lit);
        worklist_it[f]= nil;
      }

// Test, whether e or f cross their new neighbor:

      if (i>0)
      { g=current_order[i-1];
        if (cross(G, x_coord, current_pos, g, f) )
        { if (!worklist_it[g])
            worklist_it[g]= work_list.append(g);
        }
        else
        if (lit=worklist_it[g])
        { work_list.del_item(lit);
          worklist_it[g]= nil;
        }
      }

      if (i < edges.size()-2)
      { h=current_order[i+2];
        if (cross(G, x_coord, current_pos, e, h) )
          worklist_it[e]=work_list.append(e);
      }
    }
  }

  return result;
}


void init_positions(graph &G, array<list<node> > &Level,
                    node_array<int> &x_coord, node_array<int> &nlabel,
                    node_array<int> &x_prio, bool first)
{
 node   v;
 int    i=-1, label=1, x, N=G.number_of_nodes();

 while ( (++i) <= max_level)
 { x=0;
   forall(v, Level[i])
   { if (first)  x_coord[v]=x++;
     if (x_prio[v] == -1)
     { x_prio[v]= N;                      // dummy node = highest priority
       nlabel[v]= 0;
     }
     else
     { x_prio[v]= G.degree(v);
       nlabel[v]= label++;
     }
   }
 }
}


bool make_hierarchy(graph &G, node_array<int> &the_level,
array<list<node> >
```

```
                        &Level, list<node> &dummy_nodes, bool first)
{
 int    i=0;
 node   v;

 forall_nodes(v, G)
   Level[ the_level[v] ].append(v);

 if (!first) return false;



 bool   lost_edge=false;
 int    j;
 node   w, a, b;
 edge   e;
 list<edge> remove, split, turn;

 Make_Simple(G);

 forall_nodes(v, G)
 { i=the_level[v];
   forall_out_edges(e, v)
   { j=the_level[ G.target(e) ];
     if (i>j)   turn.append(e);
     if (i==j)  remove.append(e);
     if (i+1<j) split.append(e);
   }
 }

 forall(e, turn)
 {
   a=G.source(e);   b=G.target(e);

   e=G.rev_edge(e);

   if (the_level[b]+1 < the_level[a]) split.append(e);
 }

 if (!remove.empty())
 { error_handler(1,"input is not a hierarchical graph.");
   lost_edge=true;
   forall(e, remove)  G.del_edge(e);
  }



 dummy_nodes.clear();

 forall(e,split)
 {
   a = G.source(e);
   b = G.target(e);

   i = the_level[a] + 1;
   j = the_level[b];

   w = G.new_node();
   Level[i].append(w);
```

```
    dummy_nodes.append(w);
    G.move_edge(e,a,w);
    a = w;
    i++;

    while (i<j)
    { w=G.new_node();
      Level[i].append(w);
      dummy_nodes.append(w);
      G.new_edge(a,w);
      a = w;
      i++;
     }

    G.new_edge(a,b);
  }


 if (split.empty() )  return lost_edge;

 the_level.init(G);                          // there are more nodes now
 i=-1;
 while( (++i) <= max_level)
   forall(v, Level[i]) the_level[v]=i;

 return lost_edge;
}





inline int all_crossings(const graph &G, array<list<node> > &Level,
                   node_array<int> &x_coord, array<int> &L_crosses)
{
 int    i=0, crosses=0, c;

 while(i < max_level)
 { c= L_crosses[i]= number_of_crossings(G, Level, i++, x_coord);
   crosses+=c;
 }

 return crosses;
}



inline void copy_all_xcoord(const graph &G, array<list<node> >& /* Level
*/,
                             node_array<int> &x_coord, node_array<int>
&x_new,
                             array<int> &L_crosses, array<int>
&L_crosses_new)
{
 int  i=0;
 node v;

  while(i < max_level)
  { L_crosses_new[i]= L_crosses[i];
```

```
    i++;
  }
  forall_nodes(v, G)  x_new[v]=x_coord[v];
}



bool update_best(const graph &G, array<list<node> > &Level,
                    node_array<int> &x_coord, node_array<int> &x_new,
                    array<int> &L_crosses, const int &i,
                    int &crosses, const bitarray &what_to_do)

{ bool update, process_next;
  int  rcn1, rcn2=0, next_level, cr_sum, work_level;
  // int make_worse= 1.2;
  node v;

  two_level(G, Level, i, x_coord, x_coord, what_to_do);
                               // makes the requested change

  if (what_to_do & SORT_LOWER)
  { next_level=i+1;
    work_level=i+1;
  }
  else
  { next_level=i-1;
    work_level=i;
  }

  process_next=((what_to_do & SORT_LOWER) && (next_level < max_level));
  if ((what_to_do & SORT_UPPER) && (next_level > -1))
process_next=true;
                               // what level is neighbor to the changed
if any

  rcn1= number_of_crossings(G, Level, i, x_coord);
  if (process_next)
   rcn2= number_of_crossings(G, Level, next_level, x_coord);

  cr_sum= L_crosses[i];
  if (process_next) cr_sum+= L_crosses[next_level];

  update= ((rcn1+rcn2) <= cr_sum);
//  update= ((rcn1+rcn2) <= cr_sum* make_worse);



  if (update)
  { crosses= crosses- L_crosses[i]+ rcn1;
    L_crosses[i]= rcn1;
    forall(v, Level[work_level])  x_new[v]=x_coord[v];

    if (process_next)
    {  crosses= crosses- L_crosses[next_level]+ rcn2;
       L_crosses[next_level]= rcn2;
    }
  }
  else
   forall(v, Level[work_level])  x_coord[v]=x_new[v];
```

```
 return update;
}





bool down_up_sort(graph &G, array<list<node> > &Level, node_array<int>&
x_coord,
                    array<int> &L_crosses, int &crosses,
                    node_array<int>& /* nlabel */,
                    int how_often, int first, int begin)
{
 int      i=0, j=0;
 int      best_crosses, orig_crosses;
 char     headline[200];
 bool     ch, u_changes=false, l_changes=false;
 bool     result=false;

 node_array<int>    x_new(G);
 node_array<int>    x_old(G);
 array<int>  L_crosses_new(max_level);
 array<int>  L_crosses_old(max_level);
 copy_all_xcoord(G, Level, x_coord, x_old, L_crosses, L_crosses_old);

 array<bool> Lu_changes(max_level);
 array<bool> Ll_changes(max_level);
 for(i=0; i < max_level; i++)
   Lu_changes[i]=Ll_changes[i]=false;

 best_crosses= orig_crosses= crosses;



 j=how_often;
 while (j--)
 { if (best_crosses==0) break;
   if (first==DOWN)
   { for (i=begin; i< max_level; i++)
     { ch=two_level(G, Level, i, x_coord, x_coord, SORT_LOWER);
       if (ch && !Ll_changes[i]) l_changes=true;
       Ll_changes[i]=ch;
       if (ch)
       { crosses-= L_crosses[i];
         L_crosses[i]= number_of_crossings(G, Level, i, x_coord);
         crosses+= L_crosses[i];
         if (i< max_level-1)
         { crosses-= L_crosses[i+1];
           L_crosses[i+1]= number_of_crossings(G, Level, i+1, x_coord);
           crosses+= L_crosses[i+1];
         }
         if (crosses < best_crosses)
         { copy_all_xcoord(G, Level, x_coord, x_new,
              L_crosses, L_crosses_new);
           best_crosses=crosses;                    // new high score
         }
       }
```

```
      }
      begin=max_level-1;                          // set 'begin' for up-
sort new
    }
    if (best_crosses==0) break;



    for (i=begin; i>=0; i--)
    { ch=two_level(G, Level, i, x_coord, x_coord, SORT_UPPER);
      if (ch && !Lu_changes[i]) u_changes=true;
      Lu_changes[i]=ch;
      if (ch)
      { crosses-= L_crosses[i];
        L_crosses[i]= number_of_crossings(G, Level, i, x_coord);
        crosses+= L_crosses[i];
        if (i>0)
        { crosses-= L_crosses[i-1];
          L_crosses[i-1]= number_of_crossings(G, Level, i-1, x_coord);
          crosses+= L_crosses[i-1];
        }
        if (crosses < best_crosses)
        { copy_all_xcoord(G, Level, x_coord, x_new, L_crosses,
L_crosses_new);
          best_crosses=crosses;
        }
      }
    }

    first=DOWN;
    begin=0;

    if ( !(u_changes || l_changes) )  break;  else result=true;

    u_changes= l_changes= false;
  }



  if (best_crosses < orig_crosses)
  { copy_all_xcoord(G, Level, x_new, x_coord, L_crosses_new, L_crosses);
    crosses=best_crosses;
  }
  if (crosses > orig_crosses)
  { copy_all_xcoord(G, Level, x_old, x_coord, L_crosses_old, L_crosses);
    crosses=orig_crosses;
  }
  return result;
}




int down_up_change(graph &G, array<list<node> > &Level, node_array<int>
                        &x_coord, node_array<int> &nlabel, bool first)
{
```

```
 bool    skip_sort=true;
 int     i=0, j=0;
 int     crosses, prev_crosses, pprev_crosses, orig_crosses;
 char    headline[200];

 node_array<int>   x_new(G);
 node_array<int>   x_old(G);
 array<int>     L_crosses(max_level);
 array<int>     L_crosses_new(max_level);
 array<int>     L_crosses_old(max_level);

 prev_crosses= orig_crosses= crosses=
   all_crossings(G, Level, x_coord, L_crosses);
 pprev_crosses= prev_crosses+1;

 if (first)
 { down_up_sort(G, Level, x_coord, L_crosses,
                crosses, nlabel, sort_max, DOWN, 0);

#ifdef _DEBUG_SUGI
   sprintf(headline, "hierarchy after normal sort: %d crossings",
crosses);
   if (!draw_hierarchy(G, Level, x_coord, nlabel, headline, true))
user_exit();
#endif
 }

 if (crosses==0) return 0;

 copy_all_xcoord(G, Level, x_coord, x_old, L_crosses, L_crosses_old);
 copy_all_xcoord(G, Level, x_coord, x_new, L_crosses, L_crosses_new);



 j=perm_max;
 while (j--)
 { if (!skip_sort)
   { down_up_sort(G, Level, x_coord, L_crosses,
                        crosses, nlabel, 1, DOWN, 0);
     copy_all_xcoord(G, Level, x_coord, x_new,
                        L_crosses, L_crosses_new);      // update x_new
   }

   i=0;  skip_sort=false;
   while (i < max_level)                                // down loop
   { update_best(G, Level, x_coord, x_new,
        L_crosses, i, crosses, SORT_LOWER | PERMUTE);
     update_best(G, Level, x_coord, x_new,
        L_crosses, i, crosses, SORT_LOWER);
     if (crosses==0) return 0;
     i++;
   }

#ifdef _DEBUG_SUGI
   sprintf(headline, "hierarchy after down-permute, pass %d: %d
crossings",
   perm_max-j, crosses);
   if (!draw_hierarchy(G, Level, x_coord, nlabel, headline, true))
user_exit();
#endif
```

```
   i= max_level-1;
   while (i>=0)                                              // up loop
   { update_best(G, Level, x_coord, x_new,
        L_crosses, i, crosses, SORT_UPPER | PERMUTE);
     update_best(G, Level, x_coord, x_new,
        L_crosses, i, crosses, SORT_UPPER);
     if (crosses==0) return 0;
     i--;
   }
#ifdef _DEBUG_SUGI
   sprintf(headline, "hierarchy after up-permute, pass %d: %d
crossings",
   perm_max-j, crosses);
   if (!draw_hierarchy(G, Level, x_coord, nlabel, headline, true))
user_exit();
#endif

   if ((pprev_crosses== crosses) && (prev_crosses== crosses))
     break;

   pprev_crosses= prev_crosses;  prev_crosses= crosses;

 }  // outer loop



// do_debug=true;

 down_up_sort(G, Level, x_coord, L_crosses,
                          crosses, nlabel, 2, DOWN, 0);
 if (crosses > orig_crosses)
 { copy_all_xcoord(G, Level, x_old, x_coord, L_crosses_old, L_crosses);
   return orig_crosses;
 }

 return crosses;
}






int improve_coord(graph &G, node_array<int> &the_level, array<list<node>
>
                    &Level, node_array<int> &x_coord, node_array<int>
&x_prio,
                    node_array<int>& /*nlabel */)
{
 int     i, x_min=100, x_max=-100, width=0, wl=0;
 int     xv, xw, cpos, lpos, rpos, y_prev;
 node    v, w;
 edge    e;
 list_item              lit;
 node_array<list_item>  LIT(G);

 G.sort_nodes(x_coord);
```

```
 i=0;
 while (i <= max_level)  Level[i++].clear();
 forall_nodes(v, G)  LIT[v]=Level[ the_level[v] ].append(v);

 i=0;
 while (i < max_level)
  two_level(G, Level, i++, x_coord, x_prio, SORT_LOWER | IMPROVE);

#ifdef _DEBUG_SUGI
 if (!draw_hierarchy(G, Level, x_coord, nlabel, "1st down improving",
true))
     user_exit();
#endif


 while (i > 0)
  two_level(G, Level, --i, x_coord, x_prio, SORT_UPPER | IMPROVE);

#ifdef _DEBUG_SUGI
 if (!draw_hierarchy(G, Level, x_coord, nlabel, "1st up improving",
true))
     user_exit();
#endif



 i=-1;
 while ((++i) <= max_level)
 { if (Level[i].size() > width)
   { width=Level[i].size();  wl=i; }
 }

 while (wl < max_level)
  two_level(G, Level, wl++, x_coord, x_prio, SORT_LOWER | IMPROVE);

#ifdef _DEBUG_SUGI
 if (!draw_hierarchy(G, Level, x_coord, nlabel, "2nd down improving",
true))
     user_exit();
#endif



 forall_nodes(v, G)
 { cpos= lpos= rpos= 0;

   forall_out_edges(e, v)
   { w=G.target(e);
     xv=x_coord[v];  xw=x_coord[w];
     if (xv   == xw) cpos++;
     if (xv+1 == xw) rpos++;              // an edge right slanting
     if (xv-1 == xw) lpos++;
   }

   forall_in_edges(e, v)
   { w=G.source(e);
     xv=x_coord[v];  xw=x_coord[w];
     if (xv   == xw) cpos++;
     if (xv+1 == xw) rpos++;
```

```
      if (xv-1 == xw) lpos++;
    }

    if ((cpos>=rpos) && (cpos>=lpos)) continue;
    lit=LIT[v];  i=the_level[v];
    if (lpos> rpos)
    { lit=Level[i].pred(lit);
      if (lit) xw=x_coord[ Level[i].inf(lit) ];
      if (!lit || (xw != xv-1)) x_coord[v]--;
    }
    else
    { lit=Level[i].succ(lit);
      if (lit) xw=x_coord[ Level[i].inf(lit) ];
      if (!lit || (xw != xv+1)) x_coord[v]++;
    }
  }



  G.sort_nodes(x_coord);
  i=0;  y_prev=x_coord[G.first_node()];

  forall_nodes(v, G)
   if (x_coord[v] == y_prev)
   { y_prev= x_coord[v];  x_coord[v]=i; }
   else
   { y_prev= x_coord[v];  x_coord[v]=++i; }

  return i+1;
}




int SUGIYAMA_and_info(graph &G, node_array<int> &x_coord,
                         node_array<int> &the_level, list<node>
&dummy_nodes,
                         bool first= true)
{

  if (G.number_of_nodes() == 0)                 // paranoia setting
    return 0;

  int   crosses;
  node  v;

   max_level= 0;
   forall_nodes(v, G)
     if (the_level[v] > max_level)  max_level= the_level[v];

  array<list<node> > Level(max_level+1);

   if (make_hierarchy(G, the_level, Level, dummy_nodes, first) )
     return -1;
   if (first)  x_coord.init(G);
```

```
 node_array<int>   nlabel(G);
 node_array<int>   x_prio(G, 0);

  forall(v, dummy_nodes)  x_prio[v]= -1;
  init_positions(G, Level, x_coord, nlabel, x_prio, first);

#ifdef _DEBUG_SUGI
 int    i;
 char   head[200];

   i=crosses=0;
   while(i < max_level)
    crosses+= number_of_crossings(G, Level, i++, x_coord);
   sprintf(head, "original hierarchy: %d crossings", crosses);
   if (!draw_hierarchy(G, Level, x_coord, nlabel, head, true))
user_exit();
#endif



 crosses= down_up_change(G, Level, x_coord, nlabel, first);

#ifdef _DEBUG_SUGI
 sprintf(head, "Sort/permute finished with %d crossings", crosses);
 if (!draw_hierarchy(G, Level, x_coord, nlabel, head, true))
user_exit();
#endif

 int width= improve_coord(G, the_level, Level, x_coord, x_prio, nlabel);

#ifdef _DEBUG_SUGI
 if (!draw_hierarchy(G, Level, x_coord, nlabel, "final embedding",
true))
     user_exit();
#endif



 return crosses;
}



int SUGIYAMA_and_info(graph &G, node_array<int> &x_coord,
                          node_array<int> &the_level, list<node>
&dummy_nodes,
                          bool first, char *headline, file_ostream
&ps_out)
{

 if (G.number_of_nodes() == 0)                    // paranoia setting
   return 0;

 int   crosses;
 node  v;

  max_level= 0;
  forall_nodes(v, G)
    if (the_level[v] > max_level)  max_level= the_level[v];
```

```
 array<list<node> > Level(max_level+1);

  if (make_hierarchy(G, the_level, Level, dummy_nodes, first) )
     return -1;
  if (first)  x_coord.init(G);


 node_array<int>   nlabel(G);
 node_array<int>   x_prio(G, 0);

  forall(v, dummy_nodes)  x_prio[v]= -1;
  init_positions(G, Level, x_coord, nlabel, x_prio, first);

#ifdef _DEBUG_SUGI
 int    i;
 char   head[200];

   i=crosses=0;
   while(i < max_level)
    crosses+= number_of_crossings(G, Level, i++, x_coord);
   sprintf(head, "original hierarchy: %d crossings", crosses);
   if (!draw_hierarchy(G, Level, x_coord, nlabel, head, true))
user_exit();
#endif



 crosses= down_up_change(G, Level, x_coord, nlabel, first);

#ifdef _DEBUG_SUGI
 sprintf(head, "Sort/permute finished with %d crossings", crosses);
 if (!draw_hierarchy(G, Level, x_coord, nlabel, head, true))
user_exit();
#endif

 int width= improve_coord(G, the_level, Level, x_coord, x_prio, nlabel);

#ifdef _DEBUG_SUGI
 if (!draw_hierarchy(G, Level, x_coord, nlabel, "final embedding",
true))
     user_exit();
#endif



  write_to_ps(G, Level, x_coord,
               nlabel, width, max_level,
               headline, ps_out);

 return crosses;
}


int SUGIYAMA_EMBED(graph &G, node_array<int> &x_coord,
                         node_array<int> &the_level, list<node>
&dummy_nodes)
{
 return SUGIYAMA_and_info(G, x_coord, the_level, dummy_nodes, true);
```

```
}


int SUGIYAMA_iterate(graph &G, node_array<int> &x_coord,
                          node_array<int> &the_level, list<node>
&dummy_nodes)
{
 return SUGIYAMA_and_info(G, x_coord, the_level, dummy_nodes, false);
}


int SUGIYAMA_simple(const graph &G, const node_array<int> &the_level)
{
 if (G.number_of_nodes() == 0)                    // paranoia setting
   return 0;

 char    filename[200];
 node    v;
 edge    e;
 list<node>        dummy_nodes;
 graph             CG;
 node_array<node>  Cnode(G);

  forall_nodes(v, G) Cnode[v]=CG.new_node();
  forall_edges(e, G) CG.new_edge(Cnode[G.source(e)], Cnode[G.target(e)]
);

 node_array<int>   x_coord(CG);
 node_array<int>   CLevel(CG);
  forall_nodes(v, G) CLevel[Cnode[v]]=the_level[v];

  sprintf(filename, "sugi_out.ps");
  file_ostream  ps_out(filename);

 return SUGIYAMA_and_info(CG, x_coord, CLevel, dummy_nodes, true,
                          filename, ps_out);
}



int SUGIYAMA_EMBEDDING(graph &G, node_array<int>& xcoord,
                                 node_array<int>& level,
                                 edge_array<list<int> >& xpoly)
{
 list<node> dummy_nodes;

 int crossings = SUGIYAMA_and_info(G, xcoord, level, dummy_nodes, true);

 xpoly.init(G);

 node_array<bool> dummy(G,false);

 node v;
 forall(v,dummy_nodes) dummy[v] = true;
```

```
 forall_nodes(v,G)
 { if (dummy[v]) continue;
   edge e = G.first_adj_edge(v);
   while (e)
   { edge next = G.adj_succ(e);
     edge x = e;
     node u = target(x);
     while (dummy[u])
     { xpoly[e].append(xcoord[u]);
       x = G.first_adj_edge(u);
       u = target(x);
      }
     if (u != target(e))
          G.move_edge(e,source(e),u);
     e = next;
    }
 }

 forall(v,dummy_nodes) G.del_node(v);

 return crossings;
}
```

```
/*******************************************************************************
********
+
+  LEDA 3.5.1
+
+  _tutte.c
+
+  This file is part of the LEDA research version (LEDA-R) that can be
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+
*******************************************************************************
*******/
// -------------------------------------------------------------------------- //
// drawing of a graph using Tutte's algorithm                                 //
// David Alberts (1996)                                                       //
// -------------------------------------------------------------------------- //

#include <LEDA/graph_alg.h>
#include <LEDA/vector.h>
#include <LEDA/matrix.h>


bool TUTTE_EMBEDDING(const graph& G, const list<node>& fixed_nodes,
                     node_array<double>& xpos, node_array<double>& ypos)
{
  // computes a convex drawing of the graph G if possible. The list
  // fixed_nodes contains nodes with prescribed coordinates already
  // given in pos. The computed node positions of the other nodes are
  // stored in pos, too. If the operation is successful, true is
returned.
  // Precondition: pos is valid for G.

  node v,w;
  edge e;
  node_array<bool> is_fixed(G,false);
  forall(v,fixed_nodes) is_fixed[v] = true;

  list<node> other_nodes;
  forall_nodes(v,G) if(!is_fixed[v]) other_nodes.append(v);
  node_array<int> ind(G);          // position of v in other_nodes and A
  int i = 0;
  forall(v,other_nodes) ind[v] = i++;

  int n = other_nodes.size();    // #other nodes
  vector coord(n);               // coordinates (first x then y)
  vector rhs(n);                 // right hand side
  matrix A(n,n);                 // equations

  // initialize non-zero entries in matrix A
  forall(v,other_nodes)
  {
    double one_over_d = 1.0/double(G.degree(v));
    forall_inout_edges(e,v)
    {
```

```
      // get second node of e
      w = (v == source(e)) ? target(e) : source(e);
      if(!is_fixed[w]) A(ind[v],ind[w]) = one_over_d;
    }
    A(ind[v],ind[v]) = -1;
  }

  if(!A.det()) return false;

  // compute right hand side for x coordinates
  forall(v,other_nodes)
  {
    rhs[ind[v]] = 0;
    double one_over_d = 1.0/double(G.degree(v));
    forall_inout_edges(e,v)
    {
      // get second node of e
      w = (v == source(e)) ? target(e) : source(e);
      if(is_fixed[w]) rhs[ind[v]] -= (one_over_d*xpos[w]);
    }
  }

  // compute x coordinates
  coord = A.solve(rhs);
  forall(v,other_nodes) xpos[v] = coord[ind[v]];

  // compute right hand side for y coordinates
  forall(v,other_nodes)
  {
    rhs[ind[v]] = 0;
    double one_over_d = 1.0/double(G.degree(v));
    forall_inout_edges(e,v)
    {
      // get second node of e
      w = (v == source(e)) ? target(e) : source(e);
      if(is_fixed[w]) rhs[ind[v]] -= (one_over_d*ypos[w]);
    }
  }

  // compute y coordinates
  coord = A.solve(rhs);
  forall(v,other_nodes) ypos[v] = coord[ind[v]];

  return true;
}
```

APPENDIX B: CODE

A. TEST CODE CREATED

```
#include "graph_layout.h"

//
// MAIN PROGRAM
//
main()
{
GRAPH<int,int> G;

  init_graph(G, true);

  run_ortho(G, true);
  run_straight_line(G, true);
  run_straight_line2(G, true);
  run_tutte(G, true);
  run_spring_embedding(G, true);
  run_d2_spring_embedding(G, true);

return 0;

}
```

B. NEW CODE CREATED

```
#include <LEDA/graph.h>
#include <LEDA/graph_alg.h>


#ifndef GRAPH_LAYOUT_H
#define GRAPH_LAYOUT_H 1

void run_ortho(graph&, bool);
void run_straight_line(graph&, bool);
void run_straight_line2(graph&, bool);
void run_tutte(graph&, bool);
void run_d2_spring_embedding(graph&, bool);
void run_spring_embedding(graph&, bool);
void init_graph(graph&, bool);

#endif
```

```
#include <fstream.h>
#include <iostream.h>
#include <stdlib.h>
#include <stream.h>
#include "graph_layout.h"

//
//        THIS IS THE ORTHOGONAL LAYOUT ALGO
//
void run_ortho(graph& G, bool DEBUG)
{
node v;
node_array<int> x(G),y(G);
edge_array< list<int> > xbends(G), ybends(G);

if (DEBUG)
{
cout << "NO EMBEDDING       ";
newline;
}

forall_nodes(v,G)
{
   x[v] = rand_int(1,500);
   y[v] = rand_int(1,500);
}

if (DEBUG)
{
forall_nodes(v,G) cout << string("x = %3d    y = %3d\n",x[v],y[v]);
cout << "ORTHO EMBEDDING       ";
newline;
}

ORTHO_EMBEDDING(G, x, y, xbends, ybends, false);

if (DEBUG)
{
forall_nodes(v,G) cout << string("x = %3d    y = %3d\n",x[v],y[v]);
G.write_gml("graph.ortho");
}

}

//
//        THIS IS THE STRAIGHT_LINE_2 ALGO
//
void run_straight_line2(graph& G, bool DEBUG)
{
node v;
node_array<int> x(G),y(G);

if (DEBUG)
{
cout << "NO EMBEDDING       ";
newline;
}

forall_nodes(v,G)
{
   x[v] = rand_int(1,500);
```

```
   y[v] = rand_int(1,500);
}
if (DEBUG)
{
forall_nodes(v,G) cout << string("x = %3d     y = %3d\n",x[v],y[v]);
cout << "STRAIGHT LINE EMBEDDING2       ";
newline;
}

STRAIGHT_LINE_EMBEDDING2(G, x, y);

if (DEBUG)
{
forall_nodes(v,G) cout << string("x = %3d     y = %3d\n",x[v],y[v]);
G.write_gml("graph.straight_12");
}

}

//
//         THIS IS THE STRAIGHT LINE ALGO
//
void run_straight_line(graph& G, bool DEBUG)
{
node v;
node_array<int> x(G),y(G);

if (DEBUG)
{
cout << "NO EMBEDDING        ";
newline;
}

forall_nodes(v,G)
{
   x[v] = rand_int(1,500);
   y[v] = rand_int(1,500);
}
if (DEBUG)
{
forall_nodes(v,G) cout << string("x = %3d     y = %3d\n",x[v],y[v]);
cout << "STRAIGHT LINE EMBEDDING        ";
newline;
}

STRAIGHT_LINE_EMBEDDING(G, x, y);

if (DEBUG)
{
forall_nodes(v,G) cout << string("x = %3d     y = %3d\n",x[v],y[v]);
G.write_gml("graph.straight_1");
}

}

//
//       THIS IS THE TUTTE ALGO
//
void run_tutte(graph& G, bool DEBUG)
{
node_array<double> dx(G), dy(G);
```

```
list<node> L;
node v;

if (DEBUG)
{
cout << "NO EMBEDDING        ";
newline;
}


forall_nodes(v,G)
{
   dx[v] = (double) rand_int(1,500);
   dy[v] = (double) rand_int(1,500);
}
if (DEBUG)
{
forall_nodes(v,G) cout << string("x = %lf     y = %lf\n",dx[v],dy[v]);
cout << "TUTTE EMBEDDING        ";
newline;
}


TUTTE_EMBEDDING(G,L,dx,dy);

if (DEBUG)
{
forall_nodes(v,G) cout << string("x = %lf     y = %lf\n",dx[v],dy[v]);
G.write_gml("graph.tutte");
}

}

//
//       THIS IS THE D2 SPRING EMBEDDING ALGO
//
void run_d2_spring_embedding(graph& G, bool DEBUG)
{
node_array<double> dx(G), dy(G);
node v;

if (DEBUG)
{
cout << "NO EMBEDDING        ";
newline;
}

forall_nodes(v,G)
{
   dx[v] = (double) rand_int(1,500);
   dy[v] = (double) rand_int(1,500);
}
if (DEBUG)
{
forall_nodes(v,G) cout << string("x = %lf     y = %lf\n",dx[v],dy[v]);
cout << "D2 SPRING EMBEDDING EMBEDDING        ";
newline;
}


D2_SPRING_EMBEDDING(G,dx,dy,0.0,500.0,0.0,500.0,400);
```

```
if (DEBUG)
{
forall_nodes(v,G) cout << string("x = %lf     y = %lf\n",dx[v],dy[v]);
G.write_gml("graph.d2_spr_emb");
}

}

//
//       THIS IS THE SPRING EMBEDDING ALGO
//
void run_spring_embedding(graph& G, bool DEBUG)
{
node_array<double> dx(G), dy(G);
node v;

if (DEBUG)
{
cout << "NO EMBEDDING        ";
newline;
}

forall_nodes(v,G)
{
   dx[v] = (double) rand_int(1,500);
   dy[v] = (double) rand_int(1,500);
}
if (DEBUG)
{
forall_nodes(v,G) cout << string("x = %lf     y = %lf\n",dx[v],dy[v]);
cout << "SPRING EMBEDDING EMBEDDING        ";
newline;
}


SPRING_EMBEDDING(G,dx,dy,0.0,500.0,0.0,500.0,400);

if (DEBUG)
{
forall_nodes(v,G) cout << string("x = %lf     y = %lf\n",dx[v],dy[v]);
G.write_gml("graph.spr_emb");
}

}

//
//  INITIALIZE GRAPH TO BIDIRECTIONAL AND PLANAR
//
void init_graph(graph& G, bool DEBUG)
{

if (DEBUG)
{
   cout << "Inside init_graph.";
   newline;
}
int n = read_int("n = ");

random_planar_graph(G,n,n*2);
```

```
list<edge> bi_edges = Make_Bidirected(G);
G.make_map();
G.make_planar_map();

}
```

C. CAPS CODE MODIFIED

```
/*

   NOTES:


*/

/* ***********************************************************

Name:          graph_editor.C
Author:        Capt Robert M. Dixon
Program:       graph_editor
Date Modified: 21 Sep 92
Remarks:         graph_editor.C is the main program for the
           CAPS '93 graph editor.  Depending on the command line
           parameters, it allows either viewing only or full
           editing of a graph passed by the CAPS '93 syntax-
           directed editor.

General Comments:

             The XmProcessTraversal function is called numerous
           places in an attempt to keep the keyboard input focus
           in the drawing window.  This allows the editor to
           respond to the delete and backspace key.  This works
           with varying degrees of success.

Credits:         Portions of code are adapted from the following:
           Barakati, Naba, X Window System Programming, SAMS,
             1991.

           Heller, Dan, Motif Programming Manual, O'Reilly and
             Associates, 1991.

           Johnson, Eric, and Reichard, Kevin, X Window
             Applications Programming, MIS Press, 1989.

           Young, Douglas, Object Oriented Programming With C++
             and OSF/Motif, Prentice-Hall, 1992.

Reengineering:
        Modified by Doug Lange on 8/12/96
                Removed Property button and put in its place a Timers
button
        Modified by Doug Lange on 8/16/96 - 8/20/96
                Added callback and dialog for Timer Tool button.
        Modified by Doug Lange on 8/19/96
                Added callback and dialog for Informal Description Tool
button.

History:
  @1   96/09/29  Ken Moeller
```

```
      Migration from Motif 1.2 to Motif 1.1.

  @2   96/10/01  Ken Moeller
       Upgraded calling arguments to reflect changes to requirements.

  @3   96/10/03  Ken Moeller
       Started to switch over to build_from_sde and write_to_sde.
       This is not yet complete.

  @4   96/10/03  Ken Moeller
       Items removed or tests added while testing @3.

  @5   96/10/04  Ken Moeller
       Removal of viewer code.  This option is no longer supported.
       Still need to investigate the resources.  So the job is not
complete.

  @6   96/10/06  Ken Moeller
       Change in how units are encoded.

  @7   96/10/11  Ken Moeller
       Moved print command over to an XEvent so that the window
       can be refreshed before the screen is captured.

************************************************************ */

#include <fstream.h>                       //Added by DL 8/19/96
#include <iostream.h>                      //Added by DL 8/19/96
#include <stdlib.h>
#include <stream.h>
#include <sys/stat.h>                      //Added by DHA 9/18/96
#include <sys/types.h>                     //Added by DHA 9/18/96

#include <X11/Xatom.h>
#include <X11/cursorfont.h>
#include <X11/keysym.h>
#include <Xm/DialogS.h>                    //Added by DL 8/19/96
#include <Xm/DrawingA.h>
#include <Xm/DrawnB.h>
#include <Xm/Form.h>
#include <Xm/LabelG.h>
#include <Xm/List.h>
#include <Xm/MainW.h>
#include <Xm/MessageB.h>
#include <Xm/PanedW.h>                     //Added by DL 8/19/96
#include <Xm/PushB.h>                      //Added by DL 8/16/96
#include <Xm/PushBG.h>                     //Added by DL 8/19/96
#include <Xm/RowColumn.h>
#include <Xm/ScrolledW.h>
#include <Xm/SelectioB.h>
#include <Xm/Separator.h>                  //Added by DHA 8/20/96
#include <Xm/Text.h>
#include <Xm/TextF.h>
#include <Xm/ToggleBG.h>

//#include "ge_utilities_debug.h"
#include <stdio.h>
#include <math.h>

#include "action_area.h"                   //Added by DL 8/19/96
#include "build_option.h"                  //Added by DHA 8/20/96
```

```
#include "get_unique_id.h"                  //Added by MY 8/4/97
#include "ge_defs.h"                        //Added by DL 8/16/96
#include "ge_interface.h"                   //Added by DL 8/16/96
#include "gettopshell.h"                    //Added by DHA 8/19/96
#include "graph_editor.h"                   // kbm
#include "graph_object_list.h"
//#include "op_prop_exception.h"              //Added for req. 7.4, dha
9/12/96
//#include "op_prop_formal_desc.h"            //Added for req. 7.6, dha
9/15/96
//#include "op_prop_informal_desc.h"          //Added for req. 7 dha 9/15/96
//#include "op_prop_keywords.h"               //Added for req. 7.6, dha
9/15/96
//#include "op_prop_output_guard.h"           //Added for req. 7.3, dha
9/12/96
//#include "op_prop_timer_op.h"               //Added for req. 7.5, dha
9/12/96
//#include "op_prop_timing_info.h"            //Added for req. 7 & 7.7, dha
9/5/96
//#include "op_prop_trigger_cond.h"           //Added for req. 7.2, dha
9/12/96
#include "operator_object.h"
#include "postpopup.h"                      //Added by DHA 8/20/96
#include "setcursor.h"                      //Added by DHA 8/15/96
#include "spline_object.h"
#include "stream_object.h"
#include "operator_property_menu.h"
#include "stream_property_menu.h"           //Added for req. 8, dha 9/16/96
#include "timer_tool.h"                     //Added by DL 8/22/96
#include "windows.h"                        // kbm
#include "warning.h"
#include "ge_utilities_debug.h"
#include "report_errors.h"
#include "graph_layout.h"                  // Added by BR 9/6/97

//   MAXCOLORS is the number of colors defined to the editor.
// To add or subtract colors, this value must be modified.

// changed size from 75
#define BUTTONWIDTH 65
#define HELPSIZ 1000

//   graph_editor has a number of global variables due to
// Motif's use of callback functions. Since these functions
// have fixed formal parameter lists, global variables must
// be used to pass some data between functions.

//   All drawing commands are executed on both drawing_a and
// drawing_area_pixmap. drawing_a is the visible canvas, while
// drawing_area_pixmap provides a backup.  When the canvas needs
// to be redrawn, the drawing in drawing_area pixmap is merely
// copied back onto the canvas.

//   colors[] is a list of predefined X colors. To use others,
// consult an X reference giving allowable color names. Using
// the predefined colors allows the user to specify color
// preferences in X resource text files.

//   graphic_list is a GraphObjectList containing all the
// visible operators and streams.
```

```
//   selected_object_ptr always points to the object selected
// (i. e. with handles around it) on the drawing canvas.

//   num_del_ops is the number of deleted operators, and
// del_op_id is an array of identifiers for deleted operators.

//   The Resrcs struct, resources[], and options[] are used
// by Motif for parsing the command line options.


  Widget toplevel, main_w, menubar, rowcol, scrolled_win,
         op_button, term_button, stream_button, select_button,
         spec_button, informal_button, types_button,
         timers_button, button_divider;
  XtAppContext app;
  Pixmap op_button_pixmap, term_button_pixmap, stream_button_pixmap,
         select_button_pixmap, spec_button_pixmap,
informal_button_pixmap,
         types_button_pixmap,
         timers_button_pixmap;
  XGCValues gcv1, gcv2, gcv3;
  Screen *screen_ptr;
  XtActionsRec actions;
  String translations =
    "<Btn1Down>:   draw(down)\n\
     <Btn1Up>:     draw(up)   \n\
     <Btn1Motion>: draw(motion)\n\
     <Btn3Down>: draw(btn3down)\n\
     <Btn3Motion>: draw(btn3motion)\n\
     <Btn3Up>: draw(btn3up)\n\
     <MotionNotify>: draw(motionnotify)\n\
     <Key>:        draw(key)\n\
     <Key>Tab:    draw(tab)";
  unsigned long gc_mask;
  Window root_window, toplevel_window;
//  XEvent *print_event = (XEvent *) malloc(sizeof(XEvent));     // @7
  XEvent *print_event;

extern int    Global_argc;
extern char **Global_argv;

// MY 8/5/97
extern int enter_operator;
extern int enter_stream;
extern int enter_errs;
int enter_types;
int enter_spec;
int enter_timer;
int enter_inform;

// MY 8/5/97
void types_close_dialog(Widget w, XtPointer client_data, XtPointer
call_data) {
     enter_types = 0;
     close_dialog(w, client_data, call_data);
}

void spec_close_dialog(Widget w, XtPointer client_data, XtPointer
call_data) {
     enter_spec = 0;
     close_dialog(w, client_data, call_data);
```

```
}

void timer_close_dialog(Widget w, XtPointer client_data, XtPointer
call_data) {
     enter_timer = 0;
     close_dialog(w, client_data, call_data);
}

void inform_close_dialog(Widget w, XtPointer client_data, XtPointer
call_data) {
     enter_inform = 0;
     close_dialog(w, client_data, call_data);
}

int still_open()
{
    return ( enter_types || enter_spec || enter_timer || enter_inform ||
             enter_operator || enter_stream || enter_errs );
}

int is_empty(char * str)
{
    if ( *str == ' ' ) return 1;
    return 0;
}

/**********************************************************************st
ream
*** Added by Doug Lange 8/16/96.*/
GRAPH_DESC gdnode;
ID_LIST    idp;

ACTION_NODE* next_action_ptr;          // kbm

GC std_graphics_context, dotted_context, erase_context;
Dimension  width, height;
Pixmap drawing_area_pixmap;
Widget drawing_a, current_op_name, current_op_met;
Widget save_indicator, error_indicator, status_indicator;
BOOLEAN state_stream = false, alt_selected = false, ctrl_selected =
false;
BOOLEAN ibar_mode = false; // added for req #6.1. dha
BOOLEAN label_edit_mode = false; // added for req #6.1.1. dha
//MY 8/4/97
char default_name[INPUT_LINE_SIZE]; // added for req #6.4 dha
CLASS_DEF object_def = GRAPHOBJECT; // added for req #6.1. dha
char* colors[] = {"Aquamarine", "Black", "Blue", "BlueViolet",
                  "Brown", "CadetBlue", "Coral",
                  "CornflowerBlue", "Cyan", "DarkGreen",
                  "DarkOliveGreen", "DarkOrchid",
                  "DarkSlateBlue", "DarkSlateGrey",
                  "DarkTurquoise", "DimGrey", "Firebrick",
                  "ForestGreen", "Gold", "Goldenrod", "Grey",
                  "Green", "GreenYellow", "IndianRed", "Khaki",
                  "LightBlue", "LightGrey", "LightSteelBlue",
                  "LimeGreen", "Magenta", "Maroon",
                  "MediumAquamarine", "MediumBlue",
                  "MediumOrchid", "MediumSeaGreen",
                  "MediumSlateBlue", "MediumSpringGreen",
                  "MediumTurquoise", "MediumVioletRed",
                  "MidnightBlue", "Navy", "Orange", "OrangeRed",
```

```
                  "Orchid", "PaleGreen", "Pink", "Plum", "Red",
                  "Salmon", "SeaGreen", "Sienna", "SkyBlue",
                  "SlateBlue", "SpringGreen", "SteelBlue",
                  "Tan", "Thistle", "Turquoise", "Violet",
                  "VioletRed", "Wheat", "White", "Yellow",
                  "YellowGreen"};
unsigned long color_table[MAXCOLORS + 1];
TOOL_STATE tool_state = SELECT_TOOL;
GraphObjectList graphic_list;
GraphObject* selected_object_ptr = NULL;
OperatorObject *op_being_updated = NULL; // Add for req. 7, dha
StreamObject *st_being_updated = NULL;   // Add for req. 8, dha
Display *display_ptr;
Window draw_window;
int default_color = WHITE;
int default_font = COURIERBOLD12;
int num_del_ops = 0;
OP_ID del_op_id[MAXDELETEDOPS];
ERROR_MSGS  errors_present;
BOOLEAN psdl_modified, syntax_checked;
int     save_performed;         // updated save_state when you return
char *help_menu_files[] = {"psdl_grammar.hlp",
                           "operators.hlp",
                           "streams.hlp",
                           "exceptions.hlp",
                           "timers.hlp"};

// ?? Look at this to see if still needed  **************************
struct _resrcs {
  int viewer;
} Resrcs;

static XtResource resources[] = {
  {"viewer", "Viewer", XmRBoolean, sizeof (int),
   XtOffsetOf(struct _resrcs,viewer), XmRImmediate, False},
};

static XrmOptionDescRec options[] = {
  {"-v", "viewer", XrmoptionNoArg, "True"},
};

//*******************************************************************

void select_state(TOOL_STATE new_state) {

  tool_state = new_state;

  if (new_state == OPERATOR_TOOL)
    XtVaSetValues(op_button,       XmNshadowType, XmSHADOW_IN,  NULL);
  else
    XtVaSetValues(op_button,       XmNshadowType, XmSHADOW_OUT, NULL);

  if (new_state == TERMINATOR_TOOL)
    XtVaSetValues(term_button,     XmNshadowType, XmSHADOW_IN,  NULL);
  else
    XtVaSetValues(term_button,     XmNshadowType, XmSHADOW_OUT, NULL);

  if (new_state == STREAM_TOOL)
    XtVaSetValues(stream_button,   XmNshadowType, XmSHADOW_IN,  NULL);
  else
    XtVaSetValues(stream_button,   XmNshadowType, XmSHADOW_OUT, NULL);
```

```
  if (new_state == SELECT_TOOL)
    XtVaSetValues(select_button,   XmNshadowType, XmSHADOW_IN,  NULL);
  else
    XtVaSetValues(select_button,   XmNshadowType, XmSHADOW_OUT, NULL);

  // Display all other buttons
  /* ?? delete if not needed
  XtVaSetValues(types_button,    XmNshadowType, XmSHADOW_OUT, NULL);
  XtVaSetValues(spec_button,     XmNshadowType, XmSHADOW_OUT, NULL);
  XtVaSetValues(timers_button,   XmNshadowType, XmSHADOW_OUT, NULL);
  XtVaSetValues(informal_button, XmNshadowType, XmSHADOW_OUT, NULL);
  */
}


/**********************************************************************
****
 * error_label() --

**********************************************************************
***/
void error_label() {

  XmString label;

/*
 * MY 7/22/97
 */

  if ((errors_present == NULL) || (!syntax_checked)) {
    label = XmStringCreateSimple("  Check   "); // MY: Check (Syntax)
    XtVaSetValues(error_indicator, XmNlabelString, label, NULL);
    XtVaSetValues(error_indicator, XmNshadowType, XmSHADOW_OUT, NULL);
  }
  else {
    label = XmStringCreateSimple("ERROR MSGS");
    XtVaSetValues(error_indicator, XmNlabelString, label, NULL);
    XtVaSetValues(error_indicator, XmNshadowType, XmSHADOW_OUT, NULL);
  }

  XmStringFree(label);
/*
 * unmasked 8/6/97
 */
}


/**********************************************************************
****
 * save_state() -- Updates the save_indicator with the current indicated
 * state.

**********************************************************************
***/
void save_state(int state) {

  XmString label;

  if (state == NOT_MODIFIED) {
    label = XmStringCreateSimple("Save Not Required");
```

```
    XtVaSetValues(save_indicator, XmNlabelString, label, NULL);
    XtVaSetValues(save_indicator, XmNshadowType, XmSHADOW_IN, NULL);
    psdl_modified = false;
  }
  else if (state == SAVE_REQUIRED) {
    label = XmStringCreateSimple("SAVE REQUIRED");
    XtVaSetValues(save_indicator, XmNlabelString, label, NULL);
    XtVaSetValues(save_indicator, XmNshadowType, XmSHADOW_OUT, NULL);
    psdl_modified  = true;
    syntax_checked = false;
  }
  else {
    label = XmStringCreateSimple("");
    XtVaSetValues(save_indicator, XmNlabelString, label, NULL);
    XtVaSetValues(save_indicator, XmNshadowType, XmSHADOW_IN, NULL);
  }
  XmStringFree(label);

  error_label();
}


void update_status(char *status, BOOLEAN bell) {
    XtVaSetValues(status_indicator, XmNvalue, status, NULL);
    if (bell)
      XBell(display_ptr,100);
}


void clear_status() {
    XtVaSetValues(status_indicator, XmNvalue, "", NULL);
}

//   Initializes the color table.

void initialize_color_table(Screen *screen) {
  Colormap color_map = DefaultColormapOfScreen(screen);
  XColor color, unused;
  int i, screen_depth = DefaultDepthOfScreen(screen);

  if (screen_depth > 1) {              //   a color screen
    for(i = 1; i <= MAXCOLORS; i++) {
      if (!XAllocNamedColor(display_ptr, color_map,
         colors[i - 1], &color, &unused))
         printf ("Allocated unknown color: %s\n", colors[i-1]);
      color_table[i] = color.pixel;
    }
  }
  else {                             //    a black and white screen
    for(i = 1; i <= MAXCOLORS; i++) {
      if (strcmp(colors[i - 1], "White") != 0)
        color_table[i] = BlackPixelOfScreen(screen);
      else
        color_table[i] = WhitePixelOfScreen(screen);
    }
  }
}


/*********************************************************************
****
```

```
 *   Executes menu options from the 'file' menu. This is
 *   called by either the menu callback function, if the
 *   pulldown menus are used, or by the draw() function,
 *   if the alt-key combinations are used.
 *************************************************************************
**/

void handle_file_options(int item_no) {

  int  action;

  Quest_Script abort_script =
          {"","Abort changes made to graph?", "Yes", "No", "Cancel",
BTN2};
  Quest_Script save_script  =
          {"","Save changes made to graph?",  "Yes", "No", "Cancel",
BTN1};

  XFlush(display_ptr);
  switch(item_no) {

  case 0:  // Save

    // MY 8/5/97
    if ( still_open() )
    {
       warning(drawing_a, "Please close other windows first");
       break;
    }

    // Check for error condition of no Root...this should not be
possible
    next_action_ptr->option        = SAVE_TO_DISK;
    next_action_ptr->reinvoke      = true;
    free(next_action_ptr->next_op);
    next_action_ptr->next_op       = graphic_list.current_op_name();
    next_action_ptr->next_op_num = graphic_list.current_op_num();
    return_sde_flag                = true;

    break;

  case 1:  // Restore from Save

    // MY 8/5/97
    if ( still_open() )
    {
       warning(drawing_a, "Please close other windows first");
       break;
    }

    // Check for error condition of no Root...this should not be
possible
    action = YES;                        // Default action if not
modified
    if (psdl_modified)
      action = AskUser(app,drawing_a, abort_script);
    switch(action) {
        case YES:
        next_action_ptr->option        = REVERT;
        next_action_ptr->reinvoke      = true;
        free(next_action_ptr->next_op);
```

```
        next_action_ptr->next_op     = graphic_list.current_op_name();
        next_action_ptr->next_op_num = graphic_list.current_op_num();
        return_sde_flag              = true;
        break;

        case NO:
        return_sde_flag = false;  // Aborted operation, do nothing
        break;
      }

    break;

  case 2:  // Print

    // MY 8/5/97
    if ( still_open() )
    {
       warning(drawing_a, "Please close other windows first");
       break;
    }

    AskPrint(app,drawing_a, &PrintCmd);
    if (PrintCmd.answer == OK) {
      XSendEvent(display_ptr, toplevel_window, True, 0, print_event);
    }

    break;

/*
 * MY
 */
    case 3:  // Abandon Changes

    // MY 8/5/97
    if ( still_open() )
    {
       warning(drawing_a, "Please close other windows first");
       break;
    }

      Quest_Script abandon_script  =
        {"","All changes will be lost, are you sure?",
       "Yes","No","Cancel", BTN1};

      action = AskUser(app, drawing_a, abandon_script);
      if (action == YES) {
      next_action_ptr->option      = ABANDON;
      next_action_ptr->reinvoke    = true;
      free(next_action_ptr->next_op);
      next_action_ptr->next_op     = graphic_list.current_op_name();
      next_action_ptr->next_op_num = graphic_list.current_op_num();
      return_sde_flag              = true;
      }

    break;

  case 4:  // Exit

    // MY 8/5/97
    if ( still_open() )
    {
```

```
        warning(drawing_a, "Please close other windows first");
        break;
    }


    action = NO;     // Default action if not modified
                     // This is not the default save option, see
save_script
    if (psdl_modified)
      action = AskUser(app,drawing_a, save_script);

    switch(action) {
      case YES:
      next_action_ptr->option   = SAVE_TO_DISK;
      next_action_ptr->reinvoke = false;
      free(next_action_ptr->next_op);
      next_action_ptr->next_op     = graphic_list.root_op_name();
      next_action_ptr->next_op_num = graphic_list.root_op_num();
      return_sde_flag = true;
      break;

      case NO:
      next_action_ptr->option      = ABANDON;
      next_action_ptr->reinvoke    = false;
      free(next_action_ptr->next_op);
      next_action_ptr->next_op     = graphic_list.root_op_name();
      next_action_ptr->next_op_num = graphic_list.root_op_num();
      return_sde_flag              = true;
      break;

      case CANCEL:
      default:
      return_sde_flag = false;
      break;
    }

    break;

  default:

    break;
  }
}

/************************************************************************
****
*   Executes menu options from the 'psdl' menu. This is
*   called by either the menu callback function, if the
*   pulldown menus are used, or by the draw() function,
*   if the alt-key combinations are used.
************************************************************************
**/

void handle_psdl_options(int item_no) {

  int  action;
  char *opName;

  Quest_Script abort_script =
          {"","Abort changes made to graph?", "Yes", "No", "Cancel",
BTN2};
```

```
  Quest_Script save_script  =
          {"","Save changes made to graph?",  "Yes", "No", "Cancel",
BTN1};

  XFlush(display_ptr);
  switch(item_no) {

/*
 * MY
 */
  case 3:  // Syntax Check

    // MY 8/5/97
    if ( still_open() )
    {
       warning(drawing_a, "Please close other windows first");
       break;
    }

    next_action_ptr->option       = CHECK_SYNTAX;
    next_action_ptr->reinvoke     = true;
    free(next_action_ptr->next_op);
    next_action_ptr->next_op      = graphic_list.current_op_name();
    next_action_ptr->next_op_num = graphic_list.current_op_num();
    return_sde_flag              = true;

    break;

/*
 * unmasked 8/6/97
 */

  case 0:  // Go to Root

    // MY 8/5/97
    if ( still_open() )
    {
       warning(drawing_a, "Please close other windows first");
       break;
    }

    // Check for error condition of no Root...this should not be
possible
    if (graphic_list.root_op_num() == UNDEFINED_OPNUM) {
      warning(drawing_a,"No Root node defined");

      break;
    }

    next_action_ptr->option       = UPDATE_TREE;
    next_action_ptr->reinvoke     = true;
    free(next_action_ptr->next_op);
    next_action_ptr->next_op      = graphic_list.root_op_name();
    next_action_ptr->next_op_num = graphic_list.root_op_num();
    return_sde_flag              = true;

    break;

  case 1:  // Go to Parent

    // MY 8/5/97
```

```
    if ( still_open() )
    {
       warning(drawing_a, "Please close other windows first");
       break;
    }

    // Check for error condition of no Parent
    if (graphic_list.parent_op_num() == UNDEFINED_OPNUM) {
      warning(drawing_a,"No parent node defined");

      break;
    }

    next_action_ptr->option       = UPDATE_TREE;
    next_action_ptr->reinvoke     = true;
    free(next_action_ptr->next_op);
    next_action_ptr->next_op      = graphic_list.parent_op_name();
    next_action_ptr->next_op_num = graphic_list.parent_op_num();
    return_sde_flag = true;

    break;

  case 2:  // Decompose

    // MY 8/5/97
    if ( still_open() )
    {
       warning(drawing_a, "Please close other windows first");
       break;
    }

    if (selected_object_ptr == NULL)
      warning(drawing_a,"Please select an operator");

    else {
      if (selected_object_ptr->is_a() == OPERATOROBJECT) {
      opName = selected_object_ptr->name();
      if (strchr(opName,'.') != NULL) {   // Is a type
        warning(drawing_a,"Not allowed to decompose a Type Operator");
        update_status(
            "A Type Operator must be Atomic: rename or leave Atomic",
            RING_BELL);
        free(opName);
      }
      else {
        next_action_ptr->option       = UPDATE_TREE;
        next_action_ptr->reinvoke     = true;
        free(next_action_ptr->next_op);
        next_action_ptr->next_op      = opName;
        next_action_ptr->next_op_num =
                     ((OperatorObject *) selected_object_ptr)-
>op_num();
        return_sde_flag = true;
      }
      }
      else
        warning(drawing_a,"Please select an operator");
    }

    break;
```

```
  default:
    return_sde_flag = false;

    break;
  }
}


//   This function is called when a selection is made from
// the list box displayed in the 'draw_options:Color' menu.

void color_list_cb(Widget widget, XtPointer,
                     XtPointer cb_struct_ptr) {
  XmListCallbackStruct *list_struct_ptr =
    (XmListCallbackStruct *) cb_struct_ptr;

  if (selected_object_ptr != NULL) {
    if (selected_object_ptr->is_a() == OPERATOROBJECT) {
      selected_object_ptr->erase();
      selected_object_ptr->color(list_struct_ptr->item_position);
      selected_object_ptr->draw(SOLID);
      save_state(SAVE_REQUIRED);
    }
  }
  else
    default_color = list_struct_ptr->item_position;
  XtDestroyWidget(widget);
}

//   This function is called when a selection is made from
// the list box displayed in the 'draw_options:Font' menu.

void font_list_cb(Widget widget, XtPointer,
                    XtPointer cb_struct_ptr) {
  XmListCallbackStruct *list_struct_ptr =
    (XmListCallbackStruct *) cb_struct_ptr;

  if (selected_object_ptr != NULL) {
    selected_object_ptr->erase();
    selected_object_ptr->set_object_font(list_struct_ptr-
>item_position);
    selected_object_ptr->draw(SOLID);
    save_state(SAVE_REQUIRED);
  }
  else {
    default_font = list_struct_ptr->item_position;
    graphic_list.set_default_font(default_font);
  }
  XtDestroyWidget(widget);
  XmProcessTraversal(drawing_a, XmTRAVERSE_CURRENT);
}

//   This function is called when a selection is made from
// the list box displayed in the 'draw_options:Undelete Operator'
// menu.

static void op_list_cb(Widget widget, XtPointer,
                         XtPointer cb_struct_ptr) {
  XmListCallbackStruct *list_struct_ptr =
    (XmListCallbackStruct *) cb_struct_ptr;
```

```
//   The last entry in the list is 'Cancel'.
  if (list_struct_ptr->item_position != num_del_ops + 1) {

    graphic_list.set_undeleted(OPERATOROBJECT,
                               del_op_id[list_struct_ptr->item_position
- 1]);
    save_state(SAVE_REQUIRED);
    graphic_list.draw();
  }
  XtDestroyWidget(widget);
  XmProcessTraversal(drawing_a, XmTRAVERSE_CURRENT);
}

//   Executes menu options from the 'Edit' menu. This is
// called by either the menu callback function, if the
// pulldown menus are used, or by the draw() function,
// if the alt-key combinations are used.

void handle_edit_options(int item_no) {
  int i, num_items = XtNumber(colors);
  int reply;
  XmStringTable color_list, font_list, op_list;
  Widget list_box, op_box;
  char *del_op_str[MAXDELETEDOPS];

  switch(item_no) {
    case 0:

    // MY 8/5/97
    if ( still_open() )
    {
       warning(drawing_a, "Please close other windows first");
       break;
    }

      color_list =
        (XmStringTable) XtMalloc(num_items * sizeof(XmString *));
      for(i = 0; i < num_items; i++)
        color_list[i] = XmStringCreateSimple(colors[i]);
      list_box =
              XmCreateScrolledList(drawing_a, "Colors", NULL, 0);
      XtVaSetValues(list_box,
        XmNitems, color_list,
        XmNitemCount, num_items,
        XmNvisibleItemCount, 8,
        NULL);
      for(i = 0; i < num_items; i++)
        XmStringFree(color_list[i]);
      XtFree((char *) color_list);
      XtAddCallback(list_box, XmNdefaultActionCallback,
                    color_list_cb, NULL);
      XtManageChild(list_box);
      break;

    case 1:

    // MY 8/5/97
    if ( still_open() )
    {
       warning(drawing_a, "Please close other windows first");
       break;
```

```
    }

      font_list =
         (XmStringTable) XtMalloc(MAXFONTS * sizeof(XmString *));
      for(i = 0; i < MAXFONTS; i++)
        font_list[i] =
             XmStringCreateSimple(graphic_list.font_name(i + 1));
      list_box =
               XmCreateScrolledList(drawing_a, "Fonts", NULL, 0);
      XtVaSetValues(list_box,
        XmNitems, font_list,
        XmNitemCount, MAXFONTS,
        XmNvisibleItemCount, 7,
        NULL);
      for(i = 0; i < MAXFONTS; i++)
        XmStringFree(font_list[i]);
      XtFree((char *) font_list);
      XtAddCallback(list_box, XmNdefaultActionCallback,
                    font_list_cb, NULL);
      XtManageChild(list_box);
      break;

    case 2:

    // MY 8/5/97
    if ( still_open() )
    {
       warning(drawing_a, "Please close other windows first");
       break;
    }

      if (selected_object_ptr != NULL) {
        selected_object_ptr->unselect();
        selected_object_ptr = NULL;
      }
      graphic_list.get_del_op_list(del_op_str, del_op_id,
                                   num_del_ops);
      op_list = (XmStringTable)
                 XtMalloc((num_del_ops + 1) * sizeof(XmString *));
      for(i = 0; i < num_del_ops; i++)
        op_list[i] = XmStringCreateSimple(del_op_str[i]);
      op_list[num_del_ops] = XmStringCreateSimple("Cancel");
      op_box = XmCreateScrolledList(drawing_a, "Undelete",
                                    NULL, 0);
      XtVaSetValues(op_box,
                    XmNitems, op_list,
                    XmNitemCount, num_del_ops + 1,
                    XmNvisibleItemCount, 7,
                    NULL);
      for(i = 0; i < num_del_ops + 1; i++)
        XmStringFree(op_list[i]);
      XtFree((char *) op_list);
      XtAddCallback(op_box, XmNdefaultActionCallback,
                    op_list_cb, NULL);
      XtManageChild(op_box);
      break;

/*
 * MY
 *
    case 3:
```

```
    // MY 8/5/97
    if ( still_open() )
    {
       warning(drawing_a, "Please close other windows first");
       break;
    }

      Quest_Script abandon_script  =
        {"","All changes will be lost, are you sure?",
       "Yes","No","Cancel", BTN1};

      reply = AskUser(app, drawing_a, abandon_script);
      if (reply == YES) {
      next_action_ptr->option       = ABANDON;
      next_action_ptr->reinvoke     = true;
      free(next_action_ptr->next_op);
      next_action_ptr->next_op      = graphic_list.current_op_name();
      next_action_ptr->next_op_num = graphic_list.current_op_num();
      return_sde_flag               = true;
      }

    break;

 */

    case 3:
      XFillRectangle(display_ptr, drawing_area_pixmap,
                erase_context, 0, 0, width, height);
      XFillRectangle(display_ptr, draw_window,
                erase_context, 0, 0, width, height);
      graphic_list.draw();

      break;

    default:
      break;
  }
  XmProcessTraversal(drawing_a, XmTRAVERSE_CURRENT);
}

void handle_layout_options(int item_no) {
  int i, x, y, node_count;
  int to_id, from_id, icount;
  GraphObject *temp_ptr, *next_ptr;
  OperatorObject *operators[500];
  OperatorObject *obj_ptr;
  StreamObject *str_ptr;
  SplineObject *spl_ptr, spline;
  graph G;
  node* V = new node[500];

  // BUILD LEDA GRAPH FROM CAPS GRAPH
  node_count = 0;
  temp_ptr = (GraphObject *) graphic_list.cur_graph();
  G.clear();
  while (temp_ptr != NULL)
  {
    if (temp_ptr->is_a() == OPERATOROBJECT)
    {
      obj_ptr = (OperatorObject *) temp_ptr;
```

```
    V[node_count] = G.new_node();
    operators[node_count] = obj_ptr;
    obj_ptr->set_location(x,y);
    obj_ptr->set_default_text_location();
    graphic_list.move_notify(obj_ptr->is_a(), obj_ptr->id());
    cout << ".";
    node_count++;
  }
  else if (temp_ptr->is_a() == STREAMOBJECT)
  {
    str_ptr = (StreamObject *) temp_ptr;
    to_id = -9;
    from_id = -9;
    for (icount=0; icount<node_count; icount++)
    {
       if (str_ptr->to() == operators[icount]->id())
        to_id = icount;
       if (str_ptr->from() == operators[icount]->id())
        from_id = icount;
    }
    if ( (to_id >= 0) && (to_id < node_count) &&
         (from_id >= 0) && (from_id < node_count) )
    {
       G.new_edge(V[from_id], V[to_id]);
       cout << "-";
    }
    else cout << "ERROR PARSING GRAPH EDGE in handle_layout";

  }
  else
  {
    cout << "?";
  }
  next_ptr = temp_ptr->next();
  temp_ptr = next_ptr;
}
cout << endl;

// RUN ALGORITHM
switch (item_no) {
  case 0:
          cout << "Got orthoganal layout parameter" << endl;
          cout << "Got " << item_no << " parameter" << endl;
          run_ortho(G, TRUE);
          break;
  case 1:
          cout << "Got straight line 2 layout parameter" << endl;
          cout << "Got " << item_no << " parameter" << endl;
          run_straight_line2(G, TRUE);
          break;
  case 2:
          cout << "Got straight line layout parameter" << endl;
          cout << "Got " << item_no << " parameter" << endl;
          run_straight_line(G, TRUE);
          break;
  case 3:
          cout << "Got tutte layout parameter" << endl;
          cout << "Got " << item_no << " parameter" << endl;
          run_tutte(G, TRUE);
          break;
  case 4:
```

```
            cout << "Got D2 spring embedder layout parameter" << endl;
            cout << "Got " << item_no << " parameter" << endl;
            run_d2_spring_embedding(G, TRUE);
            break;
    case 5:
            cout << "Got spring embedder layout parameter" << endl;
            cout << "Got " << item_no << " parameter" << endl;
            run_spring_embedding(G, TRUE);
            break;
    default:
            cout << "Got undefined parameter" << endl;
            break;

  }

  // SET CAPS POSITIONS

  // DRAW GRAPH
  graphic_list.draw();
  // graphic_list.draw();
  // XmProcessTraversal(drawing_a, XmTRAVERSE_CURRENT);
 // warning(drawing_a,"Not yet implemented.");
}

void handle_tool_options(int item_no) {

  warning(drawing_a,"Not yet implemented.");
}

void set_color(Widget widget, char *color) {
  Display *dpy = XtDisplay(widget);
  Colormap cmap = DefaultColormapOfScreen(XtScreen(widget));
  XColor col, unused;

  if (!XAllocNamedColor(dpy, cmap, color, &col, &unused)) {
    warning(drawing_a,"Can't allocate color");
    return;
  }
  XSetForeground(dpy, std_graphics_context, col.pixel);
}


/*********************************************************************
 * Menu call-back functions.  These functions are called by the window
 * manager when a menu option is selected from a pull-down menu.  The
 * item which was selected is passed in client_data.
 *********************************************************************/

static void file_menu_cb(Widget, XtPointer client_data, XtPointer) {
  int item_no = (int) client_data;

  handle_file_options(item_no);
}

static void psdl_menu_cb(Widget, XtPointer client_data, XtPointer) {
  int item_no = (int) client_data;

  handle_psdl_options(item_no);
}

static void edit_menu_cb(Widget, XtPointer client_data, XtPointer) {
```

```
  int item_no = (int) client_data;

  handle_edit_options(item_no);
}

static void layout_menu_cb(Widget, XtPointer client_data, XtPointer) {
  int item_no = (int) client_data;

  handle_layout_options(item_no);
}

static void tool_menu_cb(Widget, XtPointer client_data, XtPointer) {
  int item_no = (int) client_data;

  handle_tool_options(item_no);
}

static void help_menu_cb(Widget w, XtPointer client_data,
                     XtPointer call_data) {
  int item_no = (int) client_data;

  help_cb(drawing_a, help_menu_files[item_no], call_data);

}

void help_cb(Widget w, XtPointer client_data, XtPointer call_data) {
// Implemented by Doug Lange 8/19/96

  Widget help_dialog, pane, text_w, rc, action_a;
  struct stat statb;

  char ch, *buf;
  int i = 0, n = 0;
  int len = 0;
  Arg     args[10];

  static ActionAreaItem   action_items[] = {
    {"OK", close_dialog, NULL}
  };

  help_dialog = XtVaCreatePopupShell("Help",
                           xmDialogShellWidgetClass, XtParent(w),
                           XmNdeleteResponse, XmDESTROY,
                           NULL);

  pane = XtVaCreateWidget("pane", xmPanedWindowWidgetClass, help_dialog,
                      XmNsashWidth,   1,
                      XmNsashHeight,  1,
                      NULL);

  rc = XtVaCreateWidget("control_area", xmRowColumnWidgetClass, pane,
NULL);

  stat((char*)client_data, &statb);
  ifstream from((char *)client_data);
  len = statb.st_size;
  buf = new char[len +1]; // Add a space for NULL
  i = 0;
  //      while (from.get(ch) && (i < HELPSIZ -1)) {
  while (from.get(ch) && (i < len)) {
    buf[i] = ch;
```

```
    i++;
  }
  buf[i] = (char)NULL;

  XtSetArg(args[n], XmNscrollVertical,        true); n++;
  XtSetArg(args[n], XmNscrollHorizontal,      false); n++;
  XtSetArg(args[n], XmNeditMode,              XmMULTI_LINE_EDIT); n++;
  XtSetArg(args[n], XmNeditable,              false); n++;
  XtSetArg(args[n], XmNcursorPositionVisible,false); n++;
  XtSetArg(args[n], XmNwordWrap,              true); n++;
  XtSetArg(args[n], XmNvalue,                 buf); n++;
  XtSetArg(args[n], XmNrows,                  20); n++;
  XtSetArg(args[n], XmNwidth,                 525); n++;
  text_w = XmCreateScrolledText(rc, "help_text", args, n);

  delete buf;

  XtManageChild(text_w);
  XtManageChild(rc);

  action_items[0].data = (XtPointer)help_dialog;
  action_a = CreateActionArea(pane, action_items,
XtNumber(action_items));

  XtManageChild(pane);
  XtPopup(help_dialog, XtGrabNone);

}


void build_menu_bar(Widget &main_w, Widget &menubar) {
  // 8/4/96 KBM  Updated for label changes in Req 4
  //             Also changed callback names to reflect new labels.

  // ?? Need to look at short-cut keys....not implemented correctly

  XmString
    file_menu,  save_opt, restore_opt, print_opt, exit_opt,
    psdl_menu,  syntax_check_opt, goto_root_opt, goto_parent_opt,
                decompose_opt,
    edit_menu,  color_opt, font_opt, undelete_opt, abandon_opt,
refresh_opt,
//  tool_menu,  reuse_lib_opt,
    layout_menu,  ortho_opt, str_line2_opt, str_line_opt, tutte_opt,
d2_se_opt,
                 spring_opt,
    help_menu,  psdl_grammar_opt, operator_opt, stream_opt,
exception_opt,
                timer_opt;

  Widget widget;

  file_menu         = XmStringCreateSimple("File");
    save_opt        = XmStringCreateSimple("Save");
    restore_opt     = XmStringCreateSimple("Restore from Save");
    print_opt       = XmStringCreateSimple("Print");
    exit_opt        = XmStringCreateSimple("Exit");

  psdl_menu         = XmStringCreateSimple("PSDL");
    syntax_check_opt= XmStringCreateSimple("Syntax Check");
    goto_root_opt   = XmStringCreateSimple("Go to Root");
```

```
    goto_parent_opt = XmStringCreateSimple("Go to Parent");
    decompose_opt   = XmStringCreateSimple("Decompose");

  edit_menu         = XmStringCreateSimple("Edit");
    color_opt       = XmStringCreateSimple("Color");
    font_opt        = XmStringCreateSimple("Font");
    undelete_opt    = XmStringCreateSimple("Undelete Operator");
    abandon_opt     = XmStringCreateSimple("Abandon Changes");
    refresh_opt     = XmStringCreateSimple("Refresh Display");
  /*
  tool_menu         = XmStringCreateSimple("Tools");
    reuse_lib_opt   = XmStringCreateSimple("Reuse Library");
  */
  printf("Just before layout menu.\n");

  layout_menu       = XmStringCreateSimple("Layout");
    ortho_opt    = XmStringCreateSimple("Orthogonal Layout");
    str_line2_opt   = XmStringCreateSimple("Straight Line 2");
    str_line_opt         = XmStringCreateSimple("Straight Line");
    tutte_opt      = XmStringCreateSimple("Tutte Layout");
    d2_se_opt          = XmStringCreateSimple("D2 Spring Embedding");
    spring_opt         = XmStringCreateSimple("Spring Embedding");

  help_menu         = XmStringCreateSimple("Help");
    psdl_grammar_opt= XmStringCreateSimple("PSDL Grammar");
    operator_opt    = XmStringCreateSimple("Operators");
    stream_opt      = XmStringCreateSimple("Streams");
    exception_opt   = XmStringCreateSimple("Exceptions");
    timer_opt       = XmStringCreateSimple("Timers");

  menubar = XmVaCreateSimpleMenuBar(main_w, "menubar",
      XmVaCASCADEBUTTON, file_menu, NULL,
      XmVaCASCADEBUTTON, psdl_menu, NULL,
      XmVaCASCADEBUTTON, edit_menu, NULL,
//    XmVaCASCADEBUTTON, tool_menu, NULL,
      XmVaCASCADEBUTTON, layout_menu, NULL,
      XmVaCASCADEBUTTON, help_menu, NULL, NULL);

  if (widget = XtNameToWidget(menubar, "button_4"))          // Assign
to help
    XtVaSetValues(menubar, XmNmenuHelpWidget, widget, NULL);

  XmVaCreateSimplePulldownMenu(menubar, "file_menu", 0, file_menu_cb,
    XmVaPUSHBUTTON, save_opt,           NULL, NULL, NULL,
    XmVaPUSHBUTTON, restore_opt,        NULL, NULL, NULL,
    XmVaPUSHBUTTON, print_opt,          NULL, NULL, NULL,
/*
 * 7/22/97 MY
 */
    XmVaPUSHBUTTON, abandon_opt,        NULL, NULL, NULL,

    XmVaPUSHBUTTON, exit_opt,           NULL, NULL, NULL,
    NULL);

  XmVaCreateSimplePulldownMenu(menubar, "psdl_menu", 1, psdl_menu_cb,
/*
 * 7/22/97 MY
 *
 *  XmVaPUSHBUTTON, syntax_check_opt, NULL, NULL, NULL,
 */
    XmVaPUSHBUTTON, goto_root_opt,     'R', NULL, NULL,
```

```
    XmVaPUSHBUTTON, goto_parent_opt,    'P', NULL, NULL,
    XmVaPUSHBUTTON, decompose_opt,      'D', NULL, NULL,
    NULL);

  XmVaCreateSimplePulldownMenu(menubar, "edit_menu", 2, edit_menu_cb,
    XmVaPUSHBUTTON, color_opt,         NULL, NULL, NULL,
    XmVaPUSHBUTTON, font_opt,          NULL, NULL, NULL,
    XmVaPUSHBUTTON, undelete_opt,      NULL, NULL, NULL,
/*
 * 7/22/97 MY
 *
 *  XmVaPUSHBUTTON, abandon_opt,       NULL, NULL, NULL,
 */
    XmVaPUSHBUTTON, refresh_opt,        'f', NULL, NULL,
    NULL);

  /*
  XmVaCreateSimplePulldownMenu(menubar, "tool_menu", 3, tool_menu_cb,
    XmVaPUSHBUTTON, reuse_lib_opt,    'U', NULL, NULL,
    NULL);
  */

  XmVaCreateSimplePulldownMenu(menubar, "layout_menu", 3,
layout_menu_cb,
    XmVaPUSHBUTTON, ortho_opt,  NULL, NULL, NULL,
    XmVaPUSHBUTTON, str_line2_opt, NULL, NULL, NULL,
    XmVaPUSHBUTTON, str_line_opt,       NULL, NULL, NULL,
    XmVaPUSHBUTTON, tutte_opt,    NULL, NULL, NULL,
    XmVaPUSHBUTTON, d2_se_opt,         NULL, NULL, NULL,
    XmVaPUSHBUTTON, spring_opt,        NULL, NULL, NULL,
    NULL);

  XmVaCreateSimplePulldownMenu(menubar, "help_menu", 4, help_menu_cb,
    XmVaPUSHBUTTON, psdl_grammar_opt, NULL, NULL, NULL,
    XmVaPUSHBUTTON, operator_opt,      NULL, NULL, NULL,
    XmVaPUSHBUTTON, stream_opt,        NULL, NULL, NULL,
    XmVaPUSHBUTTON, exception_opt,     NULL, NULL, NULL,
    XmVaPUSHBUTTON, timer_opt,         NULL, NULL, NULL,
    NULL);

  XmStringFree(file_menu);
    XmStringFree(save_opt);
    XmStringFree(restore_opt);
    XmStringFree(print_opt);
    XmStringFree(exit_opt);
  XmStringFree(psdl_menu);
    XmStringFree(syntax_check_opt);
    XmStringFree(goto_root_opt);
    XmStringFree(goto_parent_opt);
    XmStringFree(decompose_opt);
  XmStringFree(edit_menu);
    XmStringFree(color_opt);
    XmStringFree(font_opt);
    XmStringFree(undelete_opt);
    XmStringFree(abandon_opt);
    XmStringFree(refresh_opt);
//XmStringFree(tool_menu);
//  XmStringFree(reuse_lib_opt);
  XmStringFree(layout_menu);
    XmStringFree(ortho_opt);
    XmStringFree(str_line2_opt);
```

```
    XmStringFree(str_line_opt);
    XmStringFree(tutte_opt);
    XmStringFree(d2_se_opt);
    XmStringFree(spring_opt);
  XmStringFree(help_menu);
    XmStringFree(psdl_grammar_opt);
    XmStringFree(operator_opt);
    XmStringFree(stream_opt);
    XmStringFree(exception_opt);
    XmStringFree(timer_opt);
}

//   Creates the push buttons used to select the tools.

void make_buttons(Widget  &rowcol,
              Widget  &op_button,           // tools
                  Widget  &term_button,
              Widget  &stream_button,
                  Widget  &select_button,
              Widget  &types_button,        // types
              Widget  &spec_button,         // current op spec
                  Widget  &timers_button,       // current op impl
              Widget  &informal_button,     // current op impl

                  Pixmap  &op_button_pixmap,
                  Pixmap  &term_button_pixmap,
                  Pixmap  &stream_button_pixmap,
                  Pixmap  &select_button_pixmap,
                  Pixmap  &types_button_pixmap,
              Pixmap  &spec_button_pixmap,
                  Pixmap  &timers_button_pixmap,
              Pixmap  &informal_button_pixmap,
                  Display *display_ptr,
              Screen  *screen_ptr) {

  static Widget op_btn_bb, term_btn_bb, stream_btn_bb, select_btn_bb,
              types_btn_bb, spec_btn_bb, timers_btn_bb,
informal_btn_bb;

  Window root_window = RootWindowOfScreen(screen_ptr);
  unsigned int screen_depth = DefaultDepthOfScreen(screen_ptr);


  op_button_pixmap       = XCreatePixmap(display_ptr, root_window,
                         BUTTONWIDTH-4, BUTTONWIDTH-4, screen_depth);
  term_button_pixmap     = XCreatePixmap(display_ptr, root_window,
                         BUTTONWIDTH-4, BUTTONWIDTH-4, screen_depth);
  stream_button_pixmap   = XCreatePixmap(display_ptr, root_window,
                         BUTTONWIDTH-4, BUTTONWIDTH-4, screen_depth);
  select_button_pixmap   = XCreatePixmap(display_ptr, root_window,
                         BUTTONWIDTH-4, BUTTONWIDTH-4, screen_depth);
  types_button_pixmap    = XCreatePixmap(display_ptr, root_window,
                         BUTTONWIDTH-4, BUTTONWIDTH-4, screen_depth);
  spec_button_pixmap     = XCreatePixmap(display_ptr, root_window,
                         BUTTONWIDTH-4, BUTTONWIDTH-4, screen_depth);
  timers_button_pixmap   = XCreatePixmap(display_ptr, root_window,
                         BUTTONWIDTH-4, BUTTONWIDTH-4, screen_depth);
  informal_button_pixmap = XCreatePixmap(display_ptr, root_window,
                         BUTTONWIDTH-4, BUTTONWIDTH-4, screen_depth);

  XFillRectangle(display_ptr, (Drawable) op_button_pixmap,
```

```
            erase_context, 0, 0, BUTTONWIDTH-4, BUTTONWIDTH-4);
   XFillRectangle(display_ptr, (Drawable) term_button_pixmap,
            erase_context, 0, 0, BUTTONWIDTH-4, BUTTONWIDTH-4);
   XFillRectangle(display_ptr, (Drawable) stream_button_pixmap,
            erase_context, 0, 0, BUTTONWIDTH-4, BUTTONWIDTH-4);
   XFillRectangle(display_ptr, (Drawable) select_button_pixmap,
            erase_context, 0, 0, BUTTONWIDTH-4, BUTTONWIDTH-4);
   XFillRectangle(display_ptr, (Drawable) types_button_pixmap,
            erase_context, 0, 0, BUTTONWIDTH-4, BUTTONWIDTH-4);
   XFillRectangle(display_ptr, (Drawable) spec_button_pixmap,
            erase_context, 0, 0, BUTTONWIDTH-4, BUTTONWIDTH-4);
   XFillRectangle(display_ptr, (Drawable) timers_button_pixmap,
            erase_context, 0, 0, BUTTONWIDTH-4, BUTTONWIDTH-4);
   XFillRectangle(display_ptr, (Drawable) informal_button_pixmap,
            erase_context, 0, 0, BUTTONWIDTH-4, BUTTONWIDTH-4);

   XSetLineAttributes(display_ptr, std_graphics_context, 2,
                   LineSolid, CapButt, JoinMiter);

   XDrawArc(display_ptr, (Drawable) op_button_pixmap,
          std_graphics_context,
         10, 15, BUTTONWIDTH-(3*10), BUTTONWIDTH-(3*10),
         CIRCLE_BEGIN, FULL_CIRCLE);
   XDrawRectangle(display_ptr, (Drawable) term_button_pixmap,
               std_graphics_context,
            10, 15, BUTTONWIDTH-(3*10), BUTTONWIDTH-(3*10));
   XDrawLine(display_ptr, (Drawable) stream_button_pixmap,
           std_graphics_context,
          10, 15, BUTTONWIDTH-(2*10), BUTTONWIDTH-(2*10));
   XDrawString(display_ptr, (Drawable) select_button_pixmap,
             std_graphics_context, 10, (BUTTONWIDTH/2)+5, "Select", 6);
   XDrawString(display_ptr, (Drawable) types_button_pixmap,
             std_graphics_context, 10, (BUTTONWIDTH/2)+5, "Types ", 6);
   XDrawString(display_ptr, (Drawable) spec_button_pixmap,
             std_graphics_context, 10, (BUTTONWIDTH/2)+5, " Spec ", 6);
   XDrawString(display_ptr, (Drawable) timers_button_pixmap,
             std_graphics_context, 10, (BUTTONWIDTH/2)+5, "Timers", 6);
   XDrawString(display_ptr, (Drawable) informal_button_pixmap,
             std_graphics_context, 10, (BUTTONWIDTH/2)-8, "Graph ", 6);
   XDrawString(display_ptr, (Drawable) informal_button_pixmap,
             std_graphics_context, 5, (BUTTONWIDTH/2)+5, "Informal",
8);
   XDrawString(display_ptr, (Drawable) informal_button_pixmap,
             std_graphics_context, 10, (BUTTONWIDTH/2)+18, "Desc  ",
6);

   XmString button_label;

   button_label = XmStringCreateSimple("Operator");

   op_button = XtVaCreateManagedWidget("op_button",
                 xmDrawnButtonWidgetClass,
                 rowcol,
                 XmNrecomputeSize, false,
                 XmNpushButtonEnabled, false,
                 XmNshadowType, XmSHADOW_OUT,
                 XmNwidth, BUTTONWIDTH,
                 XmNheight, BUTTONWIDTH,
                 XmNlabelType, XmSTRING,
                 XmNlabelString, button_label,
                 //XmNlabelType, XmPIXMAP,
```

```
                    //XmNlabelPixmap, op_button_pixmap,
                    NULL);

  XmStringFree(button_label);
  button_label = XmStringCreateSimple("  Term");

  term_button = XtVaCreateManagedWidget("term_button",
                    xmDrawnButtonWidgetClass,
                    rowcol,
                    XmNrecomputeSize, false,
                    XmNpushButtonEnabled, false,
                    XmNshadowType, XmSHADOW_OUT,
                    XmNwidth, BUTTONWIDTH,
                    XmNheight, BUTTONWIDTH,
                    XmNlabelType, XmSTRING,
                    XmNlabelString, button_label,
                    //XmNlabelType, XmPIXMAP,
                    //XmNlabelPixmap, op_button_pixmap,
                    NULL);

  XmStringFree(button_label);
  button_label = XmStringCreateSimple(" Stream");

  stream_button = XtVaCreateManagedWidget("stream_button",
                    xmDrawnButtonWidgetClass,
                    rowcol,
                    XmNrecomputeSize, false,
                    XmNpushButtonEnabled, false,
                    XmNshadowType, XmSHADOW_OUT,
                    XmNwidth, BUTTONWIDTH,
                    XmNheight, BUTTONWIDTH,
                    XmNlabelType, XmSTRING,
                    XmNlabelString, button_label,
                    //XmNlabelType, XmPIXMAP,
                    //XmNlabelPixmap, op_button_pixmap,
                    NULL);

  XmStringFree(button_label);
  button_label = XmStringCreateSimple(" Select");

  select_button = XtVaCreateManagedWidget("select_button",
                    xmDrawnButtonWidgetClass,
                    rowcol,
                    XmNrecomputeSize, false,
                    XmNpushButtonEnabled, false,
                    XmNshadowType, XmSHADOW_OUT,
                    XmNwidth, BUTTONWIDTH,
                    XmNheight, BUTTONWIDTH,
                    XmNlabelType, XmSTRING,
                    XmNlabelString, button_label,
                    //XmNlabelType, XmPIXMAP,
                    //XmNlabelPixmap, op_button_pixmap,
                    NULL);

  XmStringFree(button_label);

  button_divider = XtVaCreateManagedWidget("separator",
                           xmSeparatorWidgetClass, rowcol,
//                     XmNy,      ROW14 - 8,
//                     XmNwidth, WIN_WIDTH,
                       NULL);
```

```
button_label = XmStringCreateSimple("  Types");

types_button = XtVaCreateManagedWidget("types_button",
                xmDrawnButtonWidgetClass,
                rowcol,
                XmNrecomputeSize, false,
                XmNpushButtonEnabled, false,
                XmNshadowType, XmSHADOW_OUT,
                XmNwidth, BUTTONWIDTH,
                XmNheight, BUTTONWIDTH,
                XmNlabelType, XmSTRING,
                XmNlabelString, button_label,
                //XmNlabelType, XmPIXMAP,
                //XmNlabelPixmap, op_button_pixmap,
                NULL);

XmStringFree(button_label);
button_label = XmStringCreateLtoR(" Parent\n  Spec",
                    XmSTRING_DEFAULT_CHARSET);

spec_button = XtVaCreateManagedWidget("spec_button",
                xmDrawnButtonWidgetClass,
                rowcol,
                XmNrecomputeSize, false,
                XmNpushButtonEnabled, false,
                XmNshadowType, XmSHADOW_OUT,
                XmNwidth, BUTTONWIDTH,
                XmNheight, BUTTONWIDTH,
                XmNlabelType, XmSTRING,
                XmNlabelString, button_label,
                //XmNlabelType, XmPIXMAP,
                //XmNlabelPixmap, op_button_pixmap,
                NULL);

XmStringFree(button_label);
button_label = XmStringCreateSimple(" Timers");

timers_button = XtVaCreateManagedWidget("timers_button",
                xmDrawnButtonWidgetClass,
                rowcol,
                XmNrecomputeSize, false,
                XmNpushButtonEnabled, false,
                XmNshadowType, XmSHADOW_OUT,
                XmNwidth, BUTTONWIDTH,
                XmNheight, BUTTONWIDTH,
                XmNlabelType, XmSTRING,
                XmNlabelString, button_label,
                //XmNlabelType, XmPIXMAP,
                //XmNlabelPixmap, op_button_pixmap,
                NULL);

XmStringFree(button_label);
button_label = XmStringCreateLtoR("  Graph\n  Desc",
                          XmSTRING_DEFAULT_CHARSET);

informal_button = XtVaCreateManagedWidget("informal_button",
                xmDrawnButtonWidgetClass,
                rowcol,
                XmNrecomputeSize, false,
```

```
                    XmNpushButtonEnabled, false,
                    XmNshadowType, XmSHADOW_OUT,
                    XmNwidth, BUTTONWIDTH,
                    XmNheight, BUTTONWIDTH,
                    XmNlabelType, XmSTRING,
                    XmNlabelString, button_label,
                    //XmNlabelType, XmPIXMAP,
                    //XmNlabelPixmap, op_button_pixmap,
                    NULL);
  XmStringFree(button_label);

  XSetLineAttributes(display_ptr, std_graphics_context, 1,
                     LineSolid, CapButt, JoinMiter);

}

//   Redraws the drawing canvas.

void redraw(Widget, XtPointer,
            XtPointer cbs) {
  XmDrawingAreaCallbackStruct *temp_ptr;

  temp_ptr = (XmDrawingAreaCallbackStruct *) cbs;
  XCopyArea(temp_ptr->event->xexpose.display,
            drawing_area_pixmap, temp_ptr->window,
            std_graphics_context, 0, 0, width, height, 0, 0);
}

//   Draws a square black box on the canvas to aid in
// graphic manipulation of objects.

void draw_handle(GC graphics_context, int x, int y) {

  x -= HANDLESIZE / 2;
  y -= HANDLESIZE / 2;
  if (x < 0)
    x = 0;
  if (y < 0)
    y = 0;

//  When the display function is set to GXxor, the pixel being
// written is exclusive-or'ed with the target pixel to
// determine color.  This means that writing the same pixel with
// the same color twice restores the original color, simplifying
// the process of erasing handles.

  XSetFunction(display_ptr, graphics_context, GXxor);
  XFillRectangle(display_ptr, draw_window, graphics_context,
                 x, y, HANDLESIZE, HANDLESIZE);
  XFillRectangle(display_ptr, drawing_area_pixmap,
                 graphics_context,
                 x, y, HANDLESIZE, HANDLESIZE);
  XSetFunction(display_ptr, graphics_context, GXcopy);
}


//   This function erases the temporary guidelines used when
// streams are drawn.
//   Dotted lines are erased first, then handles.  Since each
// handle is overwritten with the following dotted line, an
// erased handle makes an erased blotch in the beginning of the
```

```
// next segment.  When the next segment is written in xor mode,
// it makes a black mark where the erased handle overwrote the
// beginning of its segment.

void erase_guides(OP_ID from_stream_id, SplineObject *temp_spline_ptr) {
  OperatorObject *temp_operator_ptr;
  XYPAIR line_start, line_end;

  temp_spline_ptr->reset_iter();
  if (from_stream_id != UNDEFINED_OPNUM) {
    temp_operator_ptr = (OperatorObject *)
      graphic_list.target_object(OPERATOROBJECT, from_stream_id);
    line_start = temp_operator_ptr->center();
  }
  else
    line_start = temp_spline_ptr->next_pair();
  line_end = temp_spline_ptr->next_pair();
  while(line_end.x != -1) {
    XDrawLine(display_ptr, draw_window, dotted_context,
              line_start.x, line_start.y, line_end.x,
              line_end.y);
    XDrawLine(display_ptr,drawing_area_pixmap, dotted_context,
              line_start.x, line_start.y, line_end.x,
              line_end.y);
    line_start = line_end;
    line_end = temp_spline_ptr->next_pair();
  }
  temp_spline_ptr->reset_iter();
  line_end = temp_spline_ptr->next_pair();
  while(line_end.x != -1) {
    draw_handle(std_graphics_context, line_end.x, line_end.y);
    line_end = temp_spline_ptr->next_pair();
  }
}


//   This function is called when a stream is being drawn
// and the mouse is clicked on either a clear spot on the
// drawing canvas, or on top of another stream.  If a double-
// click is registered, the user wants to terminate an external
// stream.

void handle_null_point(OP_ID from_stream_id, int &last_point_x,
                       int &last_point_y,
                       int &x_state, int &y_state,
                       XEvent in_event,
                       SplineObject *temp_spline_ptr, BOOLEAN &done,
                       GraphObject *&temp_object_ptr,
                       StreamObject *&temp_stream_ptr) {

//   Checks for two clicks in the same spot.

  if ((from_stream_id != UNDEFINED_OPNUM) &&
      ((last_point_x - (HANDLESIZE / 2) - HITFUDGE)
       < in_event.xbutton.x) &&
      ((last_point_x + (HANDLESIZE / 2) + HITFUDGE)
       > in_event.xbutton.x) &&
      ((last_point_y - (HANDLESIZE / 2) - HITFUDGE)
       < in_event.xbutton.y) &&
      ((last_point_y + (HANDLESIZE / 2) + HITFUDGE)
       > in_event.xbutton.y)) {
```

```
    erase_guides(from_stream_id, temp_spline_ptr);
    OP_ID new_id = graphic_list.request_id(STREAMOBJECT);

    // MY 8/4/97
    sprintf(default_name, "noname_%d", get_unique_id());
    //MY: "" -> default_name
    temp_stream_ptr = new StreamObject(default_name, new_id,
                                       from_stream_id,
                                       0, UNDEFINED_TIME, MS,
                                   temp_spline_ptr,// @6
                                   true, false);
    temp_stream_ptr->set_object_ptrs(&graphic_list);
    graphic_list.add(temp_stream_ptr);
    save_state(SAVE_REQUIRED);
    temp_stream_ptr->draw(SOLID);
    temp_stream_ptr = NULL;
    temp_object_ptr = NULL;
    done = true;
    temp_spline_ptr->clear();
  }
  else {
    x_state = in_event.xbutton.x;
    y_state = in_event.xbutton.y;
    temp_spline_ptr->add(x_state, y_state);
    XDrawLine(display_ptr, draw_window, dotted_context,
              last_point_x, last_point_y, x_state, y_state);
    XDrawLine(display_ptr, drawing_area_pixmap, dotted_context,
              last_point_x, last_point_y, x_state, y_state);
    draw_handle(std_graphics_context, x_state, y_state);
#ifdef GE_DEBUG
//    cout << "ge: " << x_state << " " << y_state << " " <<
//      HANDLESIZE << endl;
#endif
    last_point_x = x_state;
    last_point_y = y_state;
  }
}


//   Once the user selects the Stream Tool and begins to draw,
// the draw_stream() function handles all events to speed up
// performance.

void draw_stream(int initial_x, int initial_y) {
  GraphObject *temp_object_ptr;
  OperatorObject *conv_ptr;
  XYPAIR temp_pair;
  char buffer[INPUT_LINE_SIZE]; // added for req #6.4 dha
  int count = 0; // added for req #6.4 dha
  int bufsize = INPUT_LINE_SIZE; // added for req #6.4 dha
  OP_ID from_stream_id;
  int x_state, y_state, last_point_x, last_point_y;
  unsigned long stream_event_mask =
                              (ButtonPressMask | PointerMotionMask |
                               KeyPressMask);
  unsigned long normal_mask = (ButtonPressMask | PointerMotionMask |
                               KeyPressMask |
                               ButtonMotionMask | ExposureMask |
                               ButtonReleaseMask);
  XEvent in_event;
  StreamObject *temp_stream_ptr;
```

```
  SplineObject *temp_spline_ptr;
  BOOLEAN done = false;
  KeySym keysym; // added for req #6.4 dha

  temp_spline_ptr = new SplineObject;

  temp_object_ptr = graphic_list.hit(initial_x, initial_y);
  if (temp_object_ptr == NULL) {  // External stream
    from_stream_id = UNDEFINED_OPNUM;
    temp_spline_ptr->add(initial_x, initial_y);
    x_state = initial_x;
    y_state = initial_y;
    draw_handle(std_graphics_context, x_state, y_state);
  }
  else {
    if (temp_object_ptr->is_a() != OPERATOROBJECT) {
  //  External Stream
      from_stream_id = UNDEFINED_OPNUM;
      temp_spline_ptr->add(initial_x, initial_y);
      x_state = initial_x;
      y_state = initial_y;
      draw_handle(std_graphics_context, x_state, y_state);
    }
    else {
      conv_ptr = (OperatorObject *) temp_object_ptr;
      from_stream_id = conv_ptr->id();
      temp_object_ptr = NULL;
      temp_pair = conv_ptr->center();
      x_state = temp_pair.x;
      y_state = temp_pair.y;
    }
  }
  last_point_x = x_state;
  last_point_y = y_state;
  XSelectInput(display_ptr, draw_window,
               stream_event_mask);
  while(done == false) {  // monitors the event loop
    XNextEvent(display_ptr, &in_event);
    if (in_event.xbutton.window == draw_window) {
      switch(in_event.type) {
        case MotionNotify:

#ifdef GE_DEBUG
        //          cout << "Motion" << endl;
#endif

          XDrawLine(display_ptr, draw_window, dotted_context,
                    last_point_x, last_point_y, x_state, y_state);
          XDrawLine(display_ptr, drawing_area_pixmap,
                    dotted_context, last_point_x, last_point_y,
                    x_state, y_state);
          x_state = in_event.xbutton.x;
          y_state = in_event.xbutton.y;
          XDrawLine(display_ptr, draw_window, dotted_context,
                    last_point_x, last_point_y, x_state, y_state);
          XDrawLine(display_ptr, drawing_area_pixmap,
                    dotted_context, last_point_x, last_point_y,
                    x_state, y_state);
          break;
        case ButtonPress:
        case KeyPress:
```

```
#ifdef GE_DEBUG
          if (in_event.type == ButtonPress) {
//            cout << "buttonpress" << endl;
          }
          else {
//            cout << "keypress" << endl;
          }
#endif
          XDrawLine(display_ptr, draw_window, dotted_context,
                   last_point_x, last_point_y, x_state, y_state);
          XDrawLine(display_ptr, drawing_area_pixmap,
                    dotted_context, last_point_x, last_point_y,
                    x_state, y_state);
          temp_object_ptr = graphic_list.hit(in_event.xbutton.x,
                                             in_event.xbutton.y);
          if (temp_object_ptr == NULL) {
            handle_null_point(from_stream_id, last_point_x,
                              last_point_y, x_state, y_state,
                              in_event, temp_spline_ptr, done,
                              temp_object_ptr, temp_stream_ptr);
          }
          else
            if (temp_object_ptr->is_a() == OPERATOROBJECT) {
              erase_guides(from_stream_id, temp_spline_ptr);
              OP_ID new_id = graphic_list.request_id(STREAMOBJECT);
            // MY 8/4/97
              sprintf(default_name, "noname_%d", get_unique_id());
              temp_stream_ptr =
                   //MY: "" -> default_name
                   new StreamObject(default_name, new_id,
from_stream_id,
                                           temp_object_ptr->id(),
                           UNDEFINED_TIME, MS,    // @6
                                           temp_spline_ptr, true, false);
              temp_stream_ptr->set_object_ptrs(&graphic_list);
            save_state(SAVE_REQUIRED);
              graphic_list.add(temp_stream_ptr);
              temp_stream_ptr->draw(SOLID);
              temp_stream_ptr = NULL;
              temp_object_ptr = NULL;
              done = true;
              temp_spline_ptr->clear();
          }
          else
            if (temp_object_ptr->is_a() == STREAMOBJECT) {
              handle_null_point(from_stream_id, last_point_x,
                             last_point_y, x_state, y_state,
                             in_event, temp_spline_ptr, done,
                             temp_object_ptr, temp_stream_ptr);
          }

          if (in_event.type == KeyPress) {
            count = XLookupString(&in_event.xkey, buffer,
              bufsize, &keysym, NULL);
            buffer[count] = NULL; /* add NULL terminator */

            if (keysym == XK_Escape) {

              //temp_stream_ptr->erase();
              //OP_ID deleted_op_id = temp_stream_ptr->id();
              //graphic_list.delete_notify(temp_stream_ptr->
```

```
            //                              is_a(), deleted_op_id);
            //temp_stream_ptr->set_deleted();
            //temp_stream_ptr = NULL;
            graphic_list.draw();

            done = true;
          }
          else {
            XBell(display_ptr, 100);
          }
        }
        break;

      default:
        ;
        break;
    }  //switch
  } //if right window
 }  //while done == false
 done = false;
 XSelectInput(display_ptr, draw_window, normal_mask);
}


//   Draws the outline of the text being moved.

void draw_text_shadow(int x, int y, int width, int height) {

  XDrawRectangle(display_ptr, drawing_area_pixmap,
                 dotted_context, x - width / 2, y - height / 2,
                 width, height);
  XDrawRectangle(display_ptr, draw_window, dotted_context,
                 x - width / 2, y - height / 2, width, height);
}


//   The main draw routine.  This function is called by the
// window manager every time the mouse is moved, a mouse button
// pressed, or a key pressed inside the draw window.  It is
// called with a string token that indicates why it was called,
// and processes the event accordingly.

void draw(Widget, XEvent *event, String *args, Cardinal *) { // void
draw
  static char string[INPUT_LINE_SIZE]; // added for req #6.1.1 dha
  static OperatorObject *temp_operator_ptr = NULL;
  static StreamObject *temp_stream_ptr = NULL;
  static BOOLEAN first_draw = true, handle_selected = false,
                 text_selected = false, drawing_changed = false;
  static int x_state, y_state, shadow_height, shadow_width;
  static OP_ID from_stream_id;
  GraphObject *temp_object_ptr = NULL;
  static GraphObject *ibar_object_ptr = NULL;
  char   *warningMSG;
  char buffer[INPUT_LINE_SIZE]; // added for req #6.1.1 dha
  int count = 0; // added for req #6.1.1 dha
  int length = 0; // added for req #6.1.1 dha
  int bufsize = INPUT_LINE_SIZE; // added for req #6.1.1 dha
  int x = event->xbutton.x;
  int y = event->xbutton.y;
  char *labelName;
```

```
OperatorObject *conv_op_ptr;
StreamObject *conv_st_ptr;
KeySym keysym; // added for req #6.1.1 dha
BOOLEAN state_change, type_match;
BOOLEAN type_operator;

if (strcmp(args[0], "down") == 0) {  // Button pressed
  clear_status();
  XmProcessTraversal(drawing_a, XmTRAVERSE_CURRENT);
  x_state = x;
  y_state = y;
  if (tool_state == SELECT_TOOL) {
    if (selected_object_ptr != NULL) {
      if (selected_object_ptr->hit_handle(x, y)) {
        handle_selected = true;
        object_def = selected_object_ptr->is_a();
        if (object_def == OPERATOROBJECT) {
          op_being_updated = (OperatorObject *)selected_object_ptr;
          delete temp_operator_ptr;
          conv_op_ptr = (OperatorObject *) selected_object_ptr;
          temp_operator_ptr =
            new OperatorObject("", UNDEFINED_OPNUM, UNDEFINED_OPNUM,
                     UNDEFINED_TIME, MS, conv_op_ptr->x(),   // @6
                                 conv_op_ptr->y(),
                                 conv_op_ptr->radius(),
                                 default_color, false,
                                 conv_op_ptr->is_composite(),
                                 conv_op_ptr->is_terminator());
          temp_operator_ptr->set_handle_selected(
                             conv_op_ptr->handle_selected());
        } else if (object_def == STREAMOBJECT) {
          st_being_updated = (StreamObject *)selected_object_ptr;
        }
      }  // selected_object_ptr->hit_handle()
      else {          // Unselects previously selected object
        handle_selected = false;
        selected_object_ptr->unselect();
        selected_object_ptr = NULL;
        delete temp_operator_ptr;
        temp_operator_ptr = NULL;
      }
    }  // selected_object_ptr != NULL

    if (handle_selected == false) {
      temp_object_ptr = graphic_list.hit(x, y);
      if (temp_object_ptr != NULL) {
        temp_object_ptr->select();
        selected_object_ptr = temp_object_ptr;
        text_selected = selected_object_ptr->text_selected();
        object_def = temp_object_ptr->is_a();
        if (object_def == OPERATOROBJECT) {
          op_being_updated = (OperatorObject *) temp_object_ptr;

        // Makes temporary operator to move around
          delete temp_operator_ptr;
          conv_op_ptr = (OperatorObject *) temp_object_ptr;
          temp_operator_ptr =
            new OperatorObject("", UNDEFINED_OPNUM, UNDEFINED_OPNUM,
                     UNDEFINED_TIME, MS, conv_op_ptr->x(),     // @6
                                 conv_op_ptr->y(),
                                 conv_op_ptr->radius(),
```

```
                                default_color, false,
                                conv_op_ptr->is_composite(),
                                conv_op_ptr->is_terminator());
          } else if (object_def == STREAMOBJECT) {
            st_being_updated = (StreamObject *) temp_object_ptr;
          }
        } // temp_object_ptr != NULL
        else { // No object selected
          temp_object_ptr = NULL;
          selected_object_ptr = NULL;
          delete temp_operator_ptr;
          temp_operator_ptr = NULL;
        }
      } // handle_selected == false
    } /// tool_state == SELECT_TOOL
    else {  // button down, operator tool selected?
      //      if ((((tool_state == OPERATOR_TOOL) ||
      //            (tool_state == TERMINATOR_TOOL)) &&
      //           (ibar_mode != true)) ||                    // added
8/22/96 dha,
      //         (object_def != OPERATOROBJECT)) {       //  req. 6.2 &
6.3
      if ((tool_state == OPERATOR_TOOL) ||
       (tool_state == TERMINATOR_TOOL)) {
        OP_ID new_id = graphic_list.request_id(OPERATOROBJECT);
      OP_ID new_op = graphic_list.request_id(OPERATOROBJECT);
        if (tool_state == OPERATOR_TOOL) {
        // MY 8/4/97
          sprintf(default_name, "noname_%d", get_unique_id());
          temp_operator_ptr =
          // BROCKETT 1/22/93 default x and y values changed from 0 to
100
            new OperatorObject(default_name, new_id, new_op, //MY: "" ->
default_name
                         UNDEFINED_TIME, MS, 100, 100, 30,    // @6
                              default_color, true, false,
                              false);
          temp_operator_ptr->set_location(x, y);
        } // tool_sate == OPERATOR_TOOL
        else
          if (tool_state == TERMINATOR_TOOL) {
          // MY 8/4/97
            sprintf(default_name, "noname_%d", get_unique_id());
            temp_operator_ptr =
            // BROCKETT 1/22/93 default x and y values changed from 0 to
100
              new OperatorObject(default_name, new_id, new_op, //MY: ""
-> default_p
                         UNDEFINED_TIME, MS, 100, 100, 30,  // @6
                                default_color, true, false,
                                true);
            temp_operator_ptr->set_location(x, y);
          } // tool_state == TERMINATOR_TOOL
        graphic_list.add((GraphObject *) temp_operator_ptr);
      save_state(SAVE_REQUIRED);
        temp_operator_ptr->draw(SOLID);
        temp_operator_ptr = NULL;
      }  // tool_state == OPERATOR_TOOL || TERMINATOR_TOOL && ibar_mode
||
      else // button down, stream tool selected?
        if (tool_state == STREAM_TOOL) {
```

```
          draw_stream(x, y);
        }
    }  // button down, operator tool selected?
  } else if (strcmp(args[0], "motion") == 0) {  // button not down
    if (tool_state == SELECT_TOOL) {
      if (selected_object_ptr != NULL) {
      drawing_changed = true;
      if (text_selected) {
        if (first_draw == true) {
          shadow_width = selected_object_ptr->text_width();
          shadow_height = selected_object_ptr->text_height();
          draw_text_shadow(x, y, shadow_width, shadow_height);
          first_draw = false;
        } // first_draw
        else {
          draw_text_shadow(x_state, y_state, shadow_width,
shadow_height);
          draw_text_shadow(x, y, shadow_width, shadow_height);
        }
      } // text_selected
      else
        if (selected_object_ptr->is_a() == OPERATOROBJECT) {
          if (handle_selected == true) {

            if (first_draw == true) {
            selected_object_ptr->erase();
            selected_object_ptr->unselect();
            selected_object_ptr->draw(SOLID);
            temp_operator_ptr->draw(DOTTED);
            first_draw = false;
            } // first_draw
            else {
            temp_operator_ptr->move_handle(x - x_state,
                                         y - y_state);
            }
          } // handle_selected
          else {
            if (first_draw == true)

//   Drawing the same thing twice in xor mode erases it. When
// moving an object, it is drawn once the first and last time,
// and twice afterwards

            first_draw = false;
            else
            temp_operator_ptr->draw(DOTTED);
            temp_operator_ptr->move(x - x_state, y - y_state);
            temp_operator_ptr->draw(DOTTED);
          }
        } // is_a OPERATAOROBJECT
        else {
          if (selected_object_ptr->is_a() == STREAMOBJECT) {
            if (handle_selected) {
            if (first_draw == true) {
              conv_st_ptr =
                (StreamObject *) selected_object_ptr;
              conv_st_ptr->erase_handle();
              draw_handle(std_graphics_context, x, y);
              first_draw = false;
            } // first_draw
            else {
```

```
              draw_handle(std_graphics_context, x_state, y_state);
              draw_handle(std_graphics_context, x, y);
              selected_object_ptr->move_handle(x - x_state,
                                              y - y_state);
            }
            } // handle_selected
          } // is_a STREAMOBJECT
        }

    x_state = x;
    y_state = y;
    } // selected_object_ptr != NULL
  } // tool_state == SELECT_TOOL

  // I-bar mode check
  temp_object_ptr = graphic_list.over(x, y);
  if (temp_object_ptr != NULL) {
    object_def = temp_object_ptr->is_a();
    if (object_def == OPERATOROBJECT) {

#ifdef GE_DEBUG
//          cerr << "It is an Operator Object" << endl;
#endif /* GE_DEBUG */

    ibar_mode = true;
    setcursor(drawing_a, True, XC_xterm);
    } // object_def == OPERATOROBJECT
    else
    if (object_def == STREAMOBJECT) {

#ifdef GE_DEBUG
//            cerr << "It is an Stream Object" << endl;
#endif /* GE_DEBUG */

      ibar_mode = true;
      setcursor(drawing_a, True, XC_xterm);
    } // object_def == STREAMOBJECT
    else {
      ibar_mode = false;
      setcursor(drawing_a, False, None);
    }
  } // temp_object_ptr != NULL
  else { // No object selected

#ifdef GE_DEBUG
//        cerr << "No object selected Object" << endl;
#endif /* GE_DEBUG */

    ibar_mode = false;
    setcursor(drawing_a, False, None);
  } // No object selected
} else if (strcmp(args[0], "up") == 0) {
  if (tool_state == SELECT_TOOL)
    if (selected_object_ptr != NULL) {
    if (text_selected) {
      if (first_draw == false) {
        draw_text_shadow(x_state, y_state,
                         shadow_width, shadow_height);
        selected_object_ptr->text_locate(x, y);
          save_state(SAVE_REQUIRED);
      } // first_draw
```

```
      } // text_selected
      else
        if (selected_object_ptr->is_a() == OPERATOROBJECT) {
          if (first_draw == false) {
            temp_operator_ptr->draw(DOTTED);
            XYPAIR temp_pair = temp_operator_ptr->center();
            conv_op_ptr =
            (OperatorObject *) selected_object_ptr;
            conv_op_ptr->radius(temp_operator_ptr->radius());
            conv_op_ptr->set_location(temp_pair.x,
                                      temp_pair.y);
            if (handle_selected)
            conv_op_ptr->set_default_text_location();
          } // first_draw
        } // is_a OPERATOROBJECT
        else
          if ((selected_object_ptr->is_a() == STREAMOBJECT)
             && (handle_selected)) {
            draw_handle(std_graphics_context, x_state, y_state);
          } // is_a STREAMOBJECT
      if (drawing_changed == true) {
        graphic_list.move_notify(selected_object_ptr->is_a(),
                                 selected_object_ptr->id());
        graphic_list.draw();
        save_state(SAVE_REQUIRED);
        drawing_changed = false;
      } // drawing_changed
      handle_selected = false;
      } // selected_object_ptr != NULL
    first_draw = true;
  } else if (strcmp(args[0], "btn3down") == 0) {
    clear_status();
    if (ibar_mode == true) {
      if (object_def == OPERATOROBJECT) {
      // op_being_updated = (OperatorObject *) temp_object_ptr;
      operator_property_dialog(drawing_a, op_being_updated, x, y,
                               graphic_list.cur_op_is_terminator(),
                               graphic_list.avail_impl_langs_adr(),
                               &graphic_list);
      }
      else
      if (object_def == STREAMOBJECT) {
        stream_property_dialog(drawing_a, st_being_updated, x, y,
                               &graphic_list);
        // XFlush(XtDisplay(drawing_a)); /* Stub for stream code */
      }
      else {
        XFlush(XtDisplay(drawing_a));/* Stub for Non Operator of Stream
*/
            }
    } // ibar_mode
  } else if (strcmp(args[0], "btn3motion") == 0) {
    temp_object_ptr = graphic_list.over(x, y);
    if (temp_object_ptr != NULL) {
      object_def = temp_object_ptr->is_a();
      if (object_def == OPERATOROBJECT) {

#ifdef GE_DEBUG
//          cerr << "It is an Operator Object" << endl;
#endif /* GE_DEBUG */
```

```
        ibar_mode = true;
        setcursor(drawing_a, True, XC_xterm);

        op_being_updated = (OperatorObject *) temp_object_ptr;
        }
        else
        if (object_def == STREAMOBJECT) {

#ifdef GE_DEBUG
//              cerr << "It is an Stream Object" << endl;
#endif /* GE_DEBUG */

          ibar_mode = true;
          setcursor(drawing_a, True, XC_xterm);

          st_being_updated = (StreamObject *) temp_object_ptr;

        }
        else {
          ibar_mode = false;
          setcursor(drawing_a, True, XC_left_ptr);
        }
      }
      else { // No object selected

#ifdef GE_DEBUG
        cerr << "No object selected Object" << endl;
#endif /* GE_DEBUG */

        ibar_mode = false;
        setcursor(drawing_a, False, None);
      }
    } else if (strcmp(args[0], "btn3up") == 0) {
      XFlush(XtDisplay(drawing_a)); /* Stub for stream code */
    } else if (strcmp(args[0], "motionnotify") == 0) {
      if (label_edit_mode == true) {
        label_edit_mode = false;
        if (ibar_object_ptr) {
        if (ibar_object_ptr->is_a() == STREAMOBJECT) {
          labelName = ((StreamObject *)ibar_object_ptr)->name();

          // MY
          if ( is_empty(labelName) )
          {
            sprintf(default_name, "noname_%d", get_unique_id());
            labelName = default_name;
            ((StreamObject *)ibar_object_ptr)->name(labelName);
            ((StreamObject *)ibar_object_ptr)->draw(SOLID);
          }

          warningMSG = (char *) malloc(strlen(labelName)+40);
          if (!valid_id(labelName)) {
            sprintf(warningMSG,"Invalid stream name: %s", labelName);
            warning(drawing_a, warningMSG);
            update_status(
               "Illegal stream name, retype: id ::= letter
{alpha_numeric}",
               RING_BELL);
            ((StreamObject *)ibar_object_ptr)->erase_text();

            // MY
```

```
          sprintf(default_name, "noname_%d", get_unique_id());
        ((StreamObject *)ibar_object_ptr)->name(default_name);
        //((StreamObject *)ibar_object_ptr)->name("");

        ((StreamObject *)ibar_object_ptr)->draw_text(SOLID);
      } else if (is_keyword(labelName, false)) {
        sprintf(warningMSG,"Stream name is a keyword: %s", labelName);
        warning(drawing_a, warningMSG);
        update_status("Stream name is a keyword, retype", RING_BELL);
        ((StreamObject *)ibar_object_ptr)->erase_text();

        // MY
          sprintf(default_name, "noname_%d", get_unique_id());
        ((StreamObject *)ibar_object_ptr)->name(default_name);
        //((StreamObject *)ibar_object_ptr)->name("");

        ((StreamObject *)ibar_object_ptr)->draw_text(SOLID);
      } else {
        // Valid stream name, get any existing type information
        type_match = graphic_list.fetch_matching_stream_type(
           (StreamObject *)ibar_object_ptr, &state_change);
        if (state_change)
          ((StreamObject *)ibar_object_ptr)->draw(SOLID);
      }
      free(labelName);
      free(warningMSG);
    }
    else {
      labelName = ((OperatorObject *)ibar_object_ptr)->name();
      type_operator = (strchr(labelName,'.')) ? true : false;

        // MY
        if ( is_empty(labelName) )
        {
          sprintf(default_name, "noname_%d", get_unique_id());
          labelName = default_name;
          ((OperatorObject *)ibar_object_ptr)->name(labelName);
          ((OperatorObject *)ibar_object_ptr)->draw(SOLID);
        }

      warningMSG = (char *) malloc(strlen(labelName)+80);

      if (!valid_op_id(labelName)) {
        sprintf(warningMSG,
          "Invalid operator name (syntax or keyword): %s", labelName);
        warning(drawing_a, warningMSG);
        update_status("Illegal operator name, retype:"
          " op_id ::= [id '.'] op_name ['(' [id_list] '|' [id_list]
')'",
          RING_BELL);
        ((OperatorObject *)ibar_object_ptr)->erase_text();

        // MY
          sprintf(default_name, "noname_%d", get_unique_id());
        ((OperatorObject *)ibar_object_ptr)->name(default_name);
        //((OperatorObject *)ibar_object_ptr)->name("");

        ((OperatorObject *)ibar_object_ptr)->draw_text(SOLID);
      } else if (type_operator &&
              (((OperatorObject *)ibar_object_ptr)->is_composite()))
{
```

```
          sprintf(warningMSG,
            "A Composite Operator can not be a Type: %s", labelName);
          warning(drawing_a, warningMSG);
          update_status("Composite Operator can not be a Type:"
                    " rename operator or make Automic",
                    RING_BELL);
          ((OperatorObject *)ibar_object_ptr)->erase_text();

          // MY
            sprintf(default_name, "noname_%d", get_unique_id());
          ((OperatorObject *)ibar_object_ptr)->name(default_name);
          //((OperatorObject *)ibar_object_ptr)->name("");

          ((OperatorObject *)ibar_object_ptr)->draw_text(SOLID);
        } else if (!type_operator &&
!graphic_list.unique_op_id(labelName,
                   ((OperatorObject *)ibar_object_ptr)->id())) {
          sprintf(warningMSG,
            "Simple Operator Names must be unique to level: %s",
labelName);
          warning(drawing_a, warningMSG);
          update_status("Operators that are not types must have a "
            "unique name",
            RING_BELL);
          ((OperatorObject *)ibar_object_ptr)->erase_text();

          // MY
            sprintf(default_name, "noname_%d", get_unique_id());
          ((OperatorObject *)ibar_object_ptr)->name(default_name);
          //((OperatorObject *)ibar_object_ptr)->name("");

          ((OperatorObject *)ibar_object_ptr)->draw_text(SOLID);
        }
        free(labelName);
      }
      }
      string[0] = NULL;
      buffer[0] = NULL;
      ibar_object_ptr = NULL;
    }
    temp_object_ptr = graphic_list.over(x, y);
    if (temp_object_ptr != NULL) {
      object_def = temp_object_ptr->is_a();
      if (object_def == OPERATOROBJECT) {

#ifdef GE_DEBUG
//              cerr << "It is an Operator Object" << endl;
#endif /* GE_DEBUG */

      ibar_mode = true;
      setcursor(drawing_a, True, XC_xterm);

      op_being_updated = (OperatorObject *) temp_object_ptr;
      }
      else
      if (object_def == STREAMOBJECT) {

#ifdef GE_DEBUG
//                cerr << "It is an Stream Object" << endl;
#endif /* GE_DEBUG */
```

```
        ibar_mode = true;
        setcursor(drawing_a, True, XC_xterm);

        st_being_updated = (StreamObject *) temp_object_ptr;
      }
      else {
        ibar_mode = false;
        setcursor(drawing_a, True, XC_left_ptr);
      }
    }
    else { // No object selected

#ifdef GE_DEBUG
//            cerr << "No object selected Object" << endl;
#endif /* GE_DEBUG */

      ibar_mode = false;
      setcursor(drawing_a, False, None);
    }
  } else if (strcmp(args[0], "key") == 0) {

#ifdef GE_DEBUG
//            cout << "key pressed: " << event->xkey.keycode << endl;
#endif

    count = XLookupString(&event->xkey, buffer,
                   bufsize, &keysym, NULL);
    buffer[count] = NULL; /* add NULL terminator */

    if (label_edit_mode==true) {
      if ((keysym == XK_Return) || (keysym == XK_KP_Enter) ||
       (keysym == XK_Linefeed)) {
      label_edit_mode = false;
      if (ibar_object_ptr) {
        if (ibar_object_ptr->is_a() == STREAMOBJECT) {
          labelName = ((StreamObject *)ibar_object_ptr)->name();
          warningMSG = (char *) malloc(strlen(labelName)+40);
          if (!valid_id(labelName)) {
            sprintf(warningMSG,"Invalid stream name: %s", labelName);
            warning(drawing_a, warningMSG);
            update_status(
              "Illegal stream name, retype: id ::= letter
{alpha_numeric}",
            RING_BELL);
            ((StreamObject *)ibar_object_ptr)->erase_text();
            ((StreamObject *)ibar_object_ptr)->name("");
            ((StreamObject *)ibar_object_ptr)->draw_text(SOLID);
          } else if (is_keyword(labelName, false)) {
            sprintf(warningMSG,"Stream name is a keyword: %s",
labelName);
            warning(drawing_a, warningMSG);
            update_status("Stream name is a keyword, retype",
RING_BELL);
            ((StreamObject *)ibar_object_ptr)->erase_text();
            ((StreamObject *)ibar_object_ptr)->name("");
            ((StreamObject *)ibar_object_ptr)->draw_text(SOLID);
          } else {
            // Valid stream name, get any existing type information
            type_match = graphic_list.fetch_matching_stream_type(
               (StreamObject *)ibar_object_ptr, &state_change);
            if (state_change)
```

```
            ((StreamObject *)ibar_object_ptr)->draw(SOLID);
          }
          free(labelName);
          free(warningMSG);
        }
        else {
          labelName = ((OperatorObject *)ibar_object_ptr)->name();
          type_operator = (strchr(labelName,'.')) ? true : false;

          warningMSG = (char *) malloc(strlen(labelName)+80);
          if (!valid_op_id(labelName)) {
            sprintf(warningMSG,
             "Invalid operator name (syntax or keyword): %s",
labelName);
            warning(drawing_a, warningMSG);
            update_status("Illegal operator name, retype: "
            "op_id ::= [id '.'] op_name ['(' [id_list] '|' [id_list]
')'",
            RING_BELL);
            ((OperatorObject *)ibar_object_ptr)->erase_text();
            ((OperatorObject *)ibar_object_ptr)->name("");
            ((OperatorObject *)ibar_object_ptr)->draw_text(SOLID);
          } else if ((strchr(labelName,'.') != NULL) &&
                 (((OperatorObject *)ibar_object_ptr)-
>is_composite())) {
            sprintf(warningMSG,
                  "A Composite Operator can not be a Type: %s",
labelName);
            warning(drawing_a, warningMSG);
            update_status("Composite Operator can not be a Type:"
                      " rename operator or make Automic",
                      RING_BELL);
            ((OperatorObject *)ibar_object_ptr)->erase_text();
            ((OperatorObject *)ibar_object_ptr)->name("");
            ((OperatorObject *)ibar_object_ptr)->draw_text(SOLID);
          } else if (!type_operator &&
!graphic_list.unique_op_id(labelName,
                        ((OperatorObject *)ibar_object_ptr)->id())) {
            sprintf(warningMSG,
                  "Simple Operator Names must be unique to level: %s",
                  labelName);
            warning(drawing_a, warningMSG);
            update_status("Operators that are not types must have a "
                      "unique name",
                      RING_BELL);
            ((OperatorObject *)ibar_object_ptr)->erase_text();
            ((OperatorObject *)ibar_object_ptr)->name("");
            ((OperatorObject *)ibar_object_ptr)->draw_text(SOLID);
          }
          free(labelName);
        }
      }
      string[0] = NULL;
      buffer[0] = NULL;
      ibar_object_ptr = NULL;
      }
      else
      if (((keysym >= XK_KP_Space) && (keysym <= XK_KP_9)) ||
         ((keysym >= XK_space) && (keysym <= XK_asciitilde))) {
        if ((strlen(string) + strlen(buffer)) >= INPUT_LINE_SIZE) {
          XBell(display_ptr, 100);
```

```
        }
        else {
          strcat(string, buffer);
        }
      }
      else
        if ((keysym >= XK_Shift_L) && (keysym <= XK_Hyper_R)) {
          ; /* Do nothing because it's a modifier key */
        }
        else
          if ((keysym >= XK_F1) && (keysym <= XK_F35)) {
            if (buffer[0] != (char)NULL) {
            if ((strlen(string) + strlen(buffer)) >= INPUT_LINE_SIZE) {
              XBell(display_ptr, 100);
            }
            else {
              strcat(string, buffer);
            }
            }
          }
          else
            if.((keysym == XK_BackSpace) ||
             (keysym == XK_Delete)) {
            if ((length = strlen(string)) > 0) {
              string[length - 1] = NULL;
            }
            else {
              XBell(display_ptr, 100);
            }
            }

      temp_object_ptr = graphic_list.over(x, y);
      if (temp_object_ptr != NULL) {
      object_def = temp_object_ptr->is_a();
      if (label_edit_mode != false &&
          (object_def == OPERATOROBJECT ||
           object_def == STREAMOBJECT)) {

        ibar_object_ptr = temp_object_ptr;
        temp_object_ptr->erase_text();
        temp_object_ptr->name(string);
        temp_object_ptr->draw_text(SOLID);
        save_state(SAVE_REQUIRED);
//      temp_object_ptr->unselect();
      }
      }
    }
    else
      if (alt_selected || ctrl_selected) {          // alt key pressed
      alt_selected  = false;
      ctrl_selected = false;
      switch(keysym) {
      case XK_D:                          // Decompose
      case XK_d:
        handle_psdl_options(2);         // MY: 3 -> 2
        break;
      case XK_P:                          // Goto Parent
      case XK_p:
        handle_psdl_options(1);         // MY: 2 -> 1
        break;
      case XK_R:                          // Goto Root
```

```
case XK_r:
  handle_psdl_options(0);      // MY: 1 -> 0
  break;
case XK_F:                       // Refresh Display
case XK_f:
  handle_edit_options(4);
  break;
case XK_Meta_L:                  // Alt key to activate
case XK_Meta_R:
  alt_selected = true;
  break;
case XK_Control_L:               // Control key to activate
case XK_Control_R:
  ctrl_selected = true;
  break;
default:
  break;
}
}
else if (keysym == XK_Meta_L || keysym == XK_Meta_R) {
alt_selected = true;
}
else if (keysym == XK_Control_L || keysym == XK_Control_R) {
ctrl_selected = true;
}
else
if (selected_object_ptr != NULL) {
  if ((keysym == XK_BackSpace) ||
      (keysym == XK_Delete)) {
    selected_object_ptr->erase();
    OP_ID deleted_op_id = selected_object_ptr->id();
      save_state(SAVE_REQUIRED);
    graphic_list.delete_notify(selected_object_ptr->
                          is_a(), deleted_op_id);
    selected_object_ptr->set_deleted();
    selected_object_ptr = NULL;
    graphic_list.draw();
    ibar_mode = false;
    setcursor(drawing_a, False, None);
  }
}
else
  if (ibar_mode==true &&
      label_edit_mode==false &&
      (((keysym >= XK_KP_Space) && (keysym <= XK_KP_9)) ||
       ((keysym >= XK_space) && (keysym <= XK_asciitilde)))) {
    if ((strlen(string) + strlen(buffer)) >= INPUT_LINE_SIZE) {
      XBell(display_ptr, 100);
    }
    else {
      strcat(string, buffer);
    }

    label_edit_mode = true;
    clear_status();

    temp_object_ptr = graphic_list.over(x, y);
    if (temp_object_ptr != NULL) {
      object_def = temp_object_ptr->is_a();
      if (object_def == OPERATOROBJECT ||
        object_def == STREAMOBJECT) {
```

```
            //              temp_object_ptr->select();
            ibar_object_ptr = temp_object_ptr;
            temp_object_ptr->erase_text();
            temp_object_ptr->name(string);
            temp_object_ptr->draw_text(SOLID);
            save_state(SAVE_REQUIRED);
//            temp_object_ptr->unselect();
            } // label_edit_mode != false && ()
          } // temp_object_ptr != NULL
        } // ibar_mode && label_edit_mode == false && ()
  } // strcmp KEY
} // draw


//   Callback function.  Just destroys the widget.

void widget_killer(Widget widget, XtPointer, XtPointer) {

  XtDestroyWidget(widget);
}

//   Callback function.  Called when Operator Tool button is
// pressed.

void op_button_cb(Widget, XtPointer, XtPointer) {

  select_state(OPERATOR_TOOL);

  XmProcessTraversal(drawing_a, XmTRAVERSE_CURRENT);
  if (selected_object_ptr != NULL) {
    selected_object_ptr->unselect();
    selected_object_ptr = NULL;
  }
  //??  XtVaSetValues(tool_indicator, XmNvalue, "Operator Tool", NULL);
}

//   Callback function.  Called when Terminator Tool button is
// pressed.

void term_button_cb(Widget, XtPointer, XtPointer) {

  select_state(TERMINATOR_TOOL);

  XmProcessTraversal(drawing_a, XmTRAVERSE_CURRENT);
  if (selected_object_ptr != NULL) {
    selected_object_ptr->unselect();
    selected_object_ptr = NULL;
  }
  //??  XtVaSetValues(tool_indicator, XmNvalue, "Terminator Tool",
NULL);
}


//   Null Callback.

void null_cb(Widget, XtPointer, XtPointer) {}


//  Callback function.  Called when Timer Tool OK button is
// pressed.  DL 8/22/96;  KBM 10/24/96
```

```
void timer_tool_ok_cb(Widget parent, XtPointer client_data,
                      XtPointer call_data) {

  Widget                list_w = (Widget)client_data;
  XmAnyCallbackStruct *cbs    = (XmAnyCallbackStruct *)call_data;
  int                   u_bound;
  XmString              *strlist;
  char                  *text;
  ID_LIST               op, tp;
  ID_LIST               otimer = graphic_list.timer_list(); // MY
  ID_LIST               idp, timers;

  enter_timer = 0; // MY 8/5/97

  XtVaGetValues(list_w,
                XmNitemCount,    &u_bound,
                XmNitems,        &strlist,
                NULL);

  timers = NULL;
  if (u_bound > 0) {
    idp = (ID_LIST) malloc(sizeof(ID_NODE));
    idp->next = NULL;
    //if (XmStringGetLtoR(strlist[0], XmFONTLIST_DEFAULT_TAG, &text))
//@1
    if (XmStringGetLtoR(strlist[0], XmSTRING_DEFAULT_CHARSET, &text))
//@1
      idp->id = text;
    timers = idp;

    for (int i = 1; i < u_bound; i++) {
      idp->next = (ID_LIST) malloc(sizeof(ID_NODE));
      idp = idp->next;
      idp->next = NULL;
      //if (XmStringGetLtoR(strlist[i], XmFONTLIST_DEFAULT_TAG,
&text))//@1
      if (XmStringGetLtoR(strlist[i], XmSTRING_DEFAULT_CHARSET,
&text))//@1
      idp->id = text;
    }
  }

  // MY
  op = otimer; tp = timers;
  while ( op != NULL && tp != NULL )
  {
      if ( strcmp(op->id, tp->id) != 0 ) {
            save_state(SAVE_REQUIRED);
            break;
      }
        op = op->next; tp = tp->next;
  }
  if ( op != NULL ) save_state(SAVE_REQUIRED);
  if ( tp != NULL ) save_state(SAVE_REQUIRED);

  graphic_list.timer_list(timers);
  id_list_release(timers);        timers = NULL;

  XtDestroyWidget(XtParent(XtParent(XtParent(parent))));
```

```
}

//      Callback function.  Called when Timer Tool button is
// pressed.   DL 8/16/96.

void timers_button_cb(Widget parent,XtPointer client_data,XtPointer
call_data){

  Widget   dialog, rc, pane, list, action_a;
  int      count = 0, i, n=0;
  ID_LIST  idp, timers;
  Arg      args[5];
  XmString *str,string;
  static ActionAreaItem action_items[] = {
    {"OK",      timer_tool_ok_cb,   NULL},
    {"Cancel", timer_close_dialog, NULL},
    {"Add",     timer_tool_add_cb,  NULL},
    {"Delete", timer_tool_del_cb,  NULL},
    {"Edit",    timer_tool_edit_cb, NULL},
    {"Help",    help_cb,             "timers_tool.hlp"}
  };


  // MY 8/5/97
  if ( enter_timer == 1 ) {
     putchar(007);
     return;
  }
  if ( enter_errs == 1 ) {
     putchar(007);
     warning(parent, "Please close error message window");
     return;
  }
  enter_timer = 1;

  //Build list for list widget
  timers = graphic_list.timer_list();

  idp = timers;
  while(idp) {
    count++;
    idp = idp->next;
  }
  idp = timers;
  str = (XmString *) XtMalloc (count * sizeof (XmString));
  for (i = 0; i < count; i++) {
    // str[i] = XmStringCreateLocalized(idp->id);      // @1
    str[i] = XmStringCreateSimple(idp->id);            // @1
    idp = idp->next;
  }
  id_list_release(timers);      timers = NULL;

  dialog = XtVaCreatePopupShell("dialog", xmDialogShellWidgetClass,
                         XtParent(parent), XmNtitle, "Timers Tool",
                         XmNdeleteResponse, XmDESTROY,
                         NULL);


  action_items[1].data = (XtPointer)dialog; //Set cancel buttons
client_data
```

```
  pane = XtVaCreateWidget("pane", xmPanedWindowWidgetClass, dialog,
                     XmNsashWidth,   1,
                     XmNsashHeight,  1,
                     NULL);

  rc = XtVaCreateWidget("control_area", xmRowColumnWidgetClass, pane,
NULL);
  // string = XmStringCreateLocalized("Enter or Edit Timers");    // @1
  string = XmStringCreateSimple("Enter or Edit Timers");          // @1
  XtVaCreateManagedWidget("label", xmLabelGadgetClass, rc,
                     XmNlabelString, string,
                     NULL);
  XmStringFree(string);

  list = XmCreateScrolledList(rc, "Timer_List", NULL, 0);
  XtVaSetValues(list,
            XmNvisibleItemCount, 10,
            XmNitemCount,        count,
            XmNitems,            str,
            NULL);
  XtManageChild(list);
  for(i = 0; i < count; i++)
    XmStringFree(str[i]);

  XtManageChild(rc);

  //Set client data for "OK", "Add", "Del", and "Edit" buttons
  action_items[0].data = (XtPointer)list;
  action_items[2].data = (XtPointer)list;
  action_items[3].data = (XtPointer)list;
  action_items[4].data = (XtPointer)list;

  action_a = CreateActionArea(pane, action_items,
XtNumber(action_items));

  XtManageChild(pane);
  XtPopup(dialog, XtGrabNone);

}


//      Callback function.  Called when Informal Description Tool OK is
// pressed.  Added by Doug Lange 8/19/96.

static void inform_tool_ok_pushed(Widget w, XtPointer client_data,
                                  XtPointer call_data) {

  Widget text_w = (Widget)client_data;
  XmAnyCallbackStruct *cbs = (XmAnyCallbackStruct *)call_data;

  char *text = XmTextGetString(text_w);
  char *org_text = graphic_list.graph_informal_desc();

  enter_inform = 0; // MY 8/5/97

  // MY
  if (strcmp(text, org_text) != 0) {
    graphic_list.graph_informal_desc(text);
    save_state(SAVE_REQUIRED);
  }
  free(text);
```

```
  XtDestroyWidget(XtParent(XtParent(XtParent(w))));

  clear_status();
}

//      Callback function.  Called when Informal Description Tool Button
is
// pressed.  Added by Doug Lange 8/19/96.

static void informal_button_cb(Widget w, XtPointer client_data,
                               XtPointer call_data)              {

  Widget    dialog, pane, rc, text_w, action_a;
  XmString  string;
  char      *description;

  static ActionAreaItem   action_items[] = {
    {"OK",     inform_tool_ok_pushed, NULL                      },
    {"Cancel", inform_close_dialog,   NULL                      },
    {"Help",   help_cb,               "inform_tool.hlp"   }
  };


  // MY 8/5/97
  if ( enter_inform == 1 ) {
     putchar(007);
     return;
  }
  if ( enter_errs == 1 ) {
     putchar(007);
     warning(w, "Please close error message window");
     return;
  }
  enter_inform = 1;

  dialog = XtVaCreatePopupShell ("dialog", xmDialogShellWidgetClass,
                            XtParent(w),
                            XmNtitle, "Informal Design Description",
                            XmNdeleteResponse, XmDESTROY,
                            NULL);

  action_items[1].data = (XtPointer)dialog;   //Set cancel buttons
client_data

  pane = XtVaCreateWidget("pane", xmPanedWindowWidgetClass, dialog,
                    XmNsashWidth,   1,
                    XmNsashHeight,  1,
                    NULL);

  rc = XtVaCreateWidget("control_area", xmRowColumnWidgetClass, pane,
NULL);
  string = XmStringCreateSimple("Enter or Edit Informal Description");
//@1
  XtVaCreateManagedWidget("label", xmLabelGadgetClass, rc,
                    XmNlabelString, string,
                    NULL);
  XmStringFree(string);

  description = graphic_list.graph_informal_desc();
```

```
  int      n = 0;
  Arg      args[10];
  XtSetArg(args[n], XmNrows,                    12); n++;
  XtSetArg(args[n], XmNcolumns,                 70); n++;
  XtSetArg(args[n], XmNscrollVertical,          true); n++;
  XtSetArg(args[n], XmNscrollHorizontal,        false); n++;
  XtSetArg(args[n], XmNeditMode,                XmMULTI_LINE_EDIT); n++;
  XtSetArg(args[n], XmNeditable,                true); n++;
  XtSetArg(args[n], XmNcursorPositionVisible,   true); n++;
  XtSetArg(args[n], XmNwordWrap,                true); n++;
  XtSetArg(args[n], XmNvalue,                   description); n++;
  text_w = XmCreateScrolledText(rc, "text-field", args, n);
  XtManageChild(text_w);
  //text_w = XtVaCreateManagedWidget("text-field",
xmTextFieldWidgetClass,
  //      rc, NULL);

  XtAddCallback(text_w, XmNmodifyVerifyCallback, validate_text, NULL);

  XtManageChild(rc);

  //Set client data for the "OK" and "Cancel" buttons
  action_items[0].data = (XtPointer)text_w;

  action_a = CreateActionArea(pane, action_items,
XtNumber(action_items));

  //XtAddCallback(text_w, XmNactivateCallback, activate_cb, action_a);

  XtManageChild(pane);
  free(description);
  XtPopup(dialog, XtGrabNone);

}

//   Callback function.  Called when Stream Tool button is
// pressed.

void stream_button_cb(Widget, XtPointer, XtPointer) {

  select_state(STREAM_TOOL);

  XmProcessTraversal(drawing_a, XmTRAVERSE_CURRENT);
  if (selected_object_ptr != NULL) {
    selected_object_ptr->unselect();
    selected_object_ptr = NULL;
  }
  //??  XtVaSetValues(tool_indicator, XmNvalue, "Stream Tool", NULL);
}

//   Callback function.  Called when Select Tool button is
// pressed.

void select_button_cb(Widget, XtPointer, XtPointer) {

  select_state(SELECT_TOOL);

  XmProcessTraversal(drawing_a, XmTRAVERSE_CURRENT);
  //??  XtVaSetValues(tool_indicator, XmNvalue, "Select Tool", NULL);
}
```

```
static void types_tool_ok_pushed(Widget w, XtPointer client_data,
                                 XtPointer call_data) {

  Widget text_w = (Widget)client_data;
  XmAnyCallbackStruct *cbs = (XmAnyCallbackStruct *)call_data;

  char *text = XmTextGetString(text_w);
  char *org_text = graphic_list.global_types();

  enter_types = 0; // MY 8/5/97

    /*
     * MY
     */

    {
      int ok, error_line, error_column, error_token_length;
      long l;
      XmString label;

      parse_type_spec(text, &ok, &error_line,
&error_column,&error_token_length);

        if (ok)
          printf("parser return ok\n");
        else
        {
          printf("parser return NOT ok\n");
          printf("error line   = %d\n", error_line);
          printf("error column = %d\n", error_column);
          printf("error length = %d\n", error_token_length);
          putchar(007); putchar(007); putchar(007);
          l = XmTextGetCursorPosition(text_w);
          l = (long) error_line - 1L;
          XmTextSetSelection(text_w, l, l+(long)error_token_length,
(Time)10);
          XmTextSetCursorPosition(text_w, l);

          return;
        }

    }

    /*
     * MY
     */

  if (strcmp(text, org_text) != 0) {
    graphic_list.global_types(text);
    save_state(SAVE_REQUIRED);
  }

  free(text);               text     = NULL;
  free(org_text);           org_text = NULL;

  XtDestroyWidget(XtParent(XtParent(XtParent(w))));

  clear_status();
}
```

```
void types_button_cb(Widget w, XtPointer client_data,
                 XtPointer call_data)           {

  Widget    dialog, pane, rc, text_w, action_a;
  XmString  string;
  char      *description;

  static ActionAreaItem   action_items[] = {
    {"OK",      types_tool_ok_pushed,  NULL                         },
    {"Cancel", types_close_dialog,    NULL                         },
    {"Help",    help_cb,               "types_tool.hlp"   }
  };

  // MY 8/5/97
  if ( enter_types == 1 ) {
     putchar(007);
     return;
  }
  if ( enter_errs == 1 ) {
     putchar(007);
     warning(w, "Please close error message window");
     return;
  }
  enter_types = 1;

  dialog = XtVaCreatePopupShell ("dialog", xmDialogShellWidgetClass,
                       XtParent(w),
                       XmNtitle, "Prototype Types Specification",
                       XmNdeleteResponse, XmDESTROY,
                       NULL);

  action_items[1].data = (XtPointer)dialog;   //Set cancel buttons
client_data

  pane = XtVaCreateWidget("pane", xmPanedWindowWidgetClass, dialog,
                  XmNsashWidth,   1,
                  XmNsashHeight,  1,
                  NULL);

  rc = XtVaCreateWidget("control_area", xmRowColumnWidgetClass, pane,
NULL);
  string = XmStringCreateSimple("View or Edit Prototype Types
Specification");
  XtVaCreateManagedWidget("label", xmLabelGadgetClass, rc,
                  XmNlabelString, string,
                  NULL);
  XmStringFree(string);

  description = graphic_list.global_types();

  int     n = 0;
  Arg     args[10];
  XtSetArg(args[n], XmNrows,                  12); n++;
  XtSetArg(args[n], XmNcolumns,               70); n++;
  XtSetArg(args[n], XmNscrollVertical,        true); n++;
  XtSetArg(args[n], XmNscrollHorizontal,      true); n++;
  XtSetArg(args[n], XmNeditMode,              XmMULTI_LINE_EDIT); n++;
  XtSetArg(args[n], XmNeditable,              true); n++;
  XtSetArg(args[n], XmNcursorPositionVisible, true); n++;
  XtSetArg(args[n], XmNwordWrap,              true); n++;
  XtSetArg(args[n], XmNvalue,                 description); n++;
```

```
  text_w = XmCreateScrolledText(rc, "text-field", args, n);
  XtManageChild(text_w);
  //text_w = XtVaCreateManagedWidget("text-field",
xmTextFieldWidgetClass,
  //      rc, NULL);

  //  XtAddCallback(text_w, XmNmodifyVerifyCallback, validate_text,
NULL);
  //  Note:  If you have problems with '}' symbols in the text,
uncomment
  //  the line above.

  XtManageChild(rc);

  //Set client data for the "OK" and "Cancel" buttons
  action_items[0].data = (XtPointer)text_w;

  action_a = CreateActionArea(pane, action_items,
XtNumber(action_items));

  //XtAddCallback(text_w, XmNactivateCallback, activate_cb, action_a);

  XtManageChild(pane);

/*
 * MY
 */

{
  GRAPH_DESC tmp_gd = gdnode;
  char buffer[100];
  char type_name[100];
  char type_buffer[5000];

  strcpy(type_buffer, "");
  if (strcmp(XmTextGetString(text_w), "") == 0 ||
      strcmp(XmTextGetString(text_w), "\n") == 0 )
    while ( tmp_gd->stream_list != NULL )
    {
      sprintf(type_name, "#%s#", tmp_gd->stream_list->st-
>stream_type_name);
      if ( strstr(type_buffer, type_name) == NULL && strcmp(type_name,
"##") )
      {
        sprintf(buffer, "TYPE %s\nSPECIFICATION\nEND\nIMPLEMENTATION ADA
%s END\n\n",
                tmp_gd->stream_list->st->stream_type_name,
                tmp_gd->stream_list->st->stream_type_name);
        XmTextInsert (text_w, 0L, buffer);
        strcat(type_buffer, "#");
        strcat(type_buffer, tmp_gd->stream_list->st->stream_type_name);
        strcat(type_buffer, "#");
      }
      tmp_gd->stream_list = tmp_gd->stream_list->next;
    }
}
/*
 * MY
 */

  free(description);
```

```
  XtPopup(dialog, XtGrabNone);

}

static void spec_tool_ok_pushed(Widget w, XtPointer client_data,
                              XtPointer call_data) {

  Widget text_w = (Widget)client_data;
  XmAnyCallbackStruct *cbs = (XmAnyCallbackStruct *)call_data;

  char *text = XmTextGetString(text_w);
  char *org_text = graphic_list.cur_op_spec();

  enter_spec = 0; // MY 8/5/97

    /*
     * MY
     */

    {

      int ok, error_line, error_column, error_token_length;
      long l;
      XmString label;

      parse_oper_spec(text, &ok, &error_line,
&error_column,&error_token_length);

        if (ok)
          printf("parser return ok\n");
        else
        {
          printf("parser return NOT ok\n");
          printf("error line   = %d\n", error_line);
          printf("error column = %d\n", error_column);
          printf("error length = %d\n", error_token_length);
          putchar(007); putchar(007); putchar(007);

          l = XmTextGetCursorPosition(text_w);
          l = (long) error_line - 1L;
          XmTextSetSelection(text_w, l, l+(long)error_token_length,
(Time)10);
          XmTextSetCursorPosition(text_w, l);

          return;
        }

    }

    /*
     * MY
     */

  if (strcmp(text, org_text) != 0) {
    graphic_list.cur_op_spec(text);
    save_state(SAVE_REQUIRED);
  }

  free(text);                 text     = NULL;
  free(org_text);             org_text = NULL;
```

```
  XtDestroyWidget(XtParent(XtParent(XtParent(w))));

  clear_status();
}

void spec_button_cb(Widget w, XtPointer client_data,
                XtPointer call_data)          {

  Widget    dialog, pane, rc, text_w, action_a;
  XmString  string;
  char      *description;

  static ActionAreaItem   action_items[] = {
    {"OK",     spec_tool_ok_pushed, NULL                        },
    {"Cancel", spec_close_dialog,   NULL                        },
    {"Help",   help_cb,               "spec_tool.hlp"   }
  };

  // MY 8/5/97
  if ( enter_spec == 1 ) {
     putchar(007);
     return;
  }
  if ( enter_errs == 1 ) {
     putchar(007);
     warning(w, "Please close error message window");
     return;
  }
  enter_spec = 1;

  dialog = XtVaCreatePopupShell ("dialog", xmDialogShellWidgetClass,
                          XtParent(w),
                          XmNtitle, "Prototype Specification",
                          XmNdeleteResponse, XmDESTROY,
                          NULL);

  action_items[1].data = (XtPointer)dialog;   //Set cancel buttons
client_data

  pane = XtVaCreateWidget("pane", xmPanedWindowWidgetClass, dialog,
                    XmNsashWidth,   1,
                    XmNsashHeight,  1,
                    NULL);

  rc = XtVaCreateWidget("control_area", xmRowColumnWidgetClass, pane,
NULL);
  string = XmStringCreateSimple("View or Edit Prototype Specification");
  XtVaCreateManagedWidget("label", xmLabelGadgetClass, rc,
                    XmNlabelString, string,
                    NULL);
  XmStringFree(string);

  description = graphic_list.cur_op_spec();

  int      n = 0;
  Arg      args[10];
  XtSetArg(args[n], XmNrows,                  12); n++;
  XtSetArg(args[n], XmNcolumns,               70); n++;
  XtSetArg(args[n], XmNscrollVertical,        true); n++;
  XtSetArg(args[n], XmNscrollHorizontal,      true); n++;
  XtSetArg(args[n], XmNeditMode,              XmMULTI_LINE_EDIT); n++;
```

```
  XtSetArg(args[n], XmNeditable,               true); n++;
  XtSetArg(args[n], XmNcursorPositionVisible, true); n++;
  XtSetArg(args[n], XmNwordWrap,               true); n++;
  XtSetArg(args[n], XmNvalue,                  description); n++;
  text_w = XmCreateScrolledText(rc, "text-field", args, n);
  XtManageChild(text_w);
  //text_w = XtVaCreateManagedWidget("text-field",
xmTextFieldWidgetClass,
  //      rc, NULL);

  //  XtAddCallback(text_w, XmNmodifyVerifyCallback, validate_text,
NULL);
  //  Note:  If you have problems with '}' symbols in the text,
uncomment
  //  the line above.

  XtManageChild(rc);

  //Set client data for the "OK" and "Cancel" buttons
  action_items[0].data = (XtPointer)text_w;

  action_a = CreateActionArea(pane, action_items,
XtNumber(action_items));

  //XtAddCallback(text_w, XmNactivateCallback, activate_cb, action_a);

  XtManageChild(pane);

/*
 * MY
 *
  if (strcmp(XmTextGetString(text_w), "") == 0 ||
      strcmp(XmTextGetString(text_w), "\n") == 0 )
             XmTextInsert (text_w, 0L, "SPECIFICATION\nEND");
 *
 *
 */

  free(description);
  XtPopup(dialog, XtGrabNone);


}


//   Callback function.  Called when the radio buttons in the
// properties dialog box are pushed.  Called twice: once to
// unselect old button, again to select the new one.

void radio_box_cb(Widget, XtPointer which,
                  XtPointer cbs) {
  XmToggleButtonCallbackStruct *state =
    (XmToggleButtonCallbackStruct *) cbs;

  if (state->set) {
    if ((int) which == 0)
      state_stream = false;
    else
      state_stream = true;
  }
}
```

```
void save_indicator_cb(Widget widget, XtPointer,
                   XtPointer cb_struct_ptr) {

  if (psdl_modified)
    handle_file_options(0);    // save

}

void error_indicator_cb(Widget widget, XtPointer client_data,
                   XtPointer call_data) {
/*
 * MY 7/22/97
 */

  if ((errors_present == NULL) || (!syntax_checked))
    handle_psdl_options(3);  // check syntax
  else {
    report_errors(errors_present, toplevel, next_action_ptr,
              &return_sde_flag, &prev_status);
  }
/*
 * unmasked 8/6/97
 */

}


//   If graph_editor is invoked in viewer mode, this function
// handles ClientMessage events from the syntax-directed editor.
// Commented-out code handles data passed in a property, which
// this version of the editor doesn't take advantage of.
// Used during testing, and left in for future use, if necessary.

void event_handler(Widget widget, XtPointer,
                   XEvent* in_event, Boolean*) {

  char buffer[INPUT_LINE_SIZE];
  Display *display_ptr = XtDisplayOfObject(widget);
  Window window = DefaultRootWindow(display_ptr);
//  char **data;
//  int return_count;
//  XTextProperty text_prop_return;
//  Atom property_name;
  char message_in[30];


  strcpy(message_in, in_event->xclient.data.b);
  if (strcmp(message_in, "GEDATAIN") == 0) {

    graphic_list.build_from_sde(gdnode);        // @3

#ifdef GE_DEBUG
    //    printf("graphic_list: after build\n");
    //    graphic_list.summarize();
#endif

    //  graphic_list.build_from_disk();     // @3
    graphic_list.draw();
  }
```

```
  else if (strcmp(message_in, "PrintWindow") == 0)
    {
      if (PrintCmd.op == Snd_to_Prt) {
      if ((PrintCmd.printer != NULL) && (*PrintCmd.printer != '\0')) {
        sprintf(buffer,
              "xwd -frame -id %d | xpr -gray 2 -device ps | lpr -P%s ",
              XtWindow(toplevel), PrintCmd.printer);
      }
      else {
        sprintf(buffer,
              "xwd -frame -id %d | xpr -gray 2 -device ps | lpr ",
              XtWindow(toplevel));
      }
      setcursor(toplevel,True,XC_watch);
      system(buffer);
      setcursor(toplevel,True,XC_left_ptr);
      }
      else {
      if ((PrintCmd.file != NULL) && (*PrintCmd.file != '\0')) {
        sprintf(buffer,
              "xwd -frame -id %d > %s ",
              XtWindow(toplevel), PrintCmd.file);
      }
      else {
        warning(drawing_a,"A file name must be suppled.");
      }
      setcursor(toplevel,True,XC_watch);
      system(buffer);
      setcursor(toplevel,True,XC_left_ptr);
      }
    }
  else {
#ifdef GE_DEBUG
//      cout << "Event " << message_in << endl;
#endif
    }
}


void set_current_op() {

  char *cur_op_name;

  cur_op_name = graphic_list.current_op_name();
  if (cur_op_name != NULL)
    XtVaSetValues(current_op_name, XmNvalue, cur_op_name, NULL);
  free(cur_op_name);
}

void set_current_op_met() {

  char buffer[25] = "MET ";
  char *time;
  char *met = buffer;

  if (graphic_list.cur_op_spec_met() != UNDEFINED_TIME) {
    time = time_with_units(graphic_list.cur_op_spec_met(),
                     graphic_list.cur_op_spec_met_unit());
    strncat(met,time,20);
    XtVaSetValues(current_op_met, XmNvalue, met, NULL);
    free(time);
```

```
  }
  else
    XtVaSetValues(current_op_met, XmNvalue, "", NULL);
}

void set_editor_title() {

  char   title_str[63] = "PSDL Editor: \0";
  char   *title_ptr = title_str;
  char   *name_ptr;

  name_ptr = graphic_list.root_op_name();
  if (name_ptr != NULL)
    strncat(title_ptr,name_ptr,50);
  XtVaSetValues(toplevel, XmNtitle, title_ptr, NULL);
  free(name_ptr);
}


void init_motif() {

  // Simulated arguments
  //  char*   args[] = {"edit_graph","-geometry","800x600",NULL};
  //  int     signed_argc = 3;
  //  char**  argv = args;

  char*  args[] = {"edit_graph","-geometry","800x600",NULL};
  int    Global_argc = 3;
  char** Global_argv = args;

  char   title_str[63] = "PSDL Editor: \0";
  char   *title_ptr = title_str;
  XmString tmp;

  print_event = (XEvent *) malloc(sizeof(XEvent));     // @7

  toplevel = XtVaAppInitialize(&app, "edit_graph", options,
                               XtNumber(options), &Global_argc,
Global_argv,
                               NULL, NULL);

  display_ptr = XtDisplay(toplevel);
  XtGetApplicationResources(toplevel, (XtPointer) &Resrcs,
                            resources, XtNumber(resources),
                            NULL, 0);
  screen_ptr = XtScreen(toplevel);
  initialize_color_table(screen_ptr);
  root_window = RootWindowOfScreen(screen_ptr);
  gcv1.foreground = BlackPixelOfScreen(screen_ptr);
  gcv1.background = WhitePixelOfScreen(screen_ptr);
  gcv2.foreground = BlackPixelOfScreen(screen_ptr);
  gcv2.background = WhitePixelOfScreen(screen_ptr);
  gcv3.foreground = WhitePixelOfScreen(screen_ptr);
  gcv3.background = WhitePixelOfScreen(screen_ptr);
  gc_mask = GCForeground | GCBackground;
  std_graphics_context = XCreateGC(display_ptr,
                           root_window, gc_mask, &gcv1);
  dotted_context = XCreateGC(display_ptr,
                       root_window, gc_mask, &gcv2);
  erase_context = XCreateGC(display_ptr, root_window, gc_mask,
                            &gcv3);
```

```
XSetLineAttributes(display_ptr, dotted_context, 1,
                   LineOnOffDash, CapButt, JoinMiter);
XSetFunction(display_ptr, dotted_context, GXxor);

main_w = XtVaCreateManagedWidget("main_w", xmFormWidgetClass,
                         toplevel, NULL);
build_menu_bar(main_w, menubar);
XtManageChild(menubar);
rowcol =
  XtVaCreateManagedWidget("rowcol", xmRowColumnWidgetClass,
                    main_w,
                    XmNnumColumns, 1,
                    //        XmNorientation,  XmHORIZONTAL,
                    NULL);

make_buttons(rowcol,
          op_button, term_button, stream_button, select_button,
          types_button, spec_button,
          timers_button, informal_button,
          op_button_pixmap, term_button_pixmap,
          stream_button_pixmap, select_button_pixmap,
          types_button_pixmap, spec_button_pixmap,
          informal_button_pixmap, timers_button_pixmap,
          display_ptr, screen_ptr);

  XtAddCallback(op_button,        XmNactivateCallback, op_button_cb,
NULL);
  XtAddCallback(term_button,      XmNactivateCallback, term_button_cb,
NULL);
  XtAddCallback(stream_button,    XmNactivateCallback, stream_button_cb,
NULL);
  XtAddCallback(select_button,    XmNactivateCallback, select_button_cb,
NULL);
  XtAddCallback(types_button,     XmNactivateCallback, types_button_cb,
NULL);
  XtAddCallback(spec_button,      XmNactivateCallback, spec_button_cb,
NULL);
  XtAddCallback(timers_button,    XmNactivateCallback, timers_button_cb,
NULL);
  XtAddCallback(informal_button, XmNactivateCallback,
informal_button_cb,NULL);

  XtVaSetValues(toplevel, XmNtitle, title_ptr, NULL);

  current_op_name =
    XtVaCreateManagedWidget("current_op_name", xmTextWidgetClass,
                    main_w,
                    XmNvalue, "",
                    XmNshadowThickness, 1,
                    NULL);

  current_op_met =
    XtVaCreateManagedWidget("current_op_met", xmTextWidgetClass,
                    main_w,
                    XmNvalue, "",
                    XmNwidth, 150,
                    XmNshadowThickness, 1,
                    NULL);

  scrolled_win =
    XtVaCreateManagedWidget("scrolled_win",
```

```
                    xmScrolledWindowWidgetClass,
                    main_w,
                    // XmNwidth, 1200,
                    // XmNheight, 750,
                    XmNscrollingPolicy, XmAUTOMATIC,
                    XmNscrollBarDisplayPolicy, XmAS_NEEDED,
                    NULL);
  actions.string = "draw";
  actions.proc = draw;
  XtAppAddActions(app, &actions, 1);
  status_indicator =
    XtVaCreateManagedWidget("satus_indicator", xmTextWidgetClass,
                    main_w,
                    XmNheight, 31,
                    XmNvalue, "",
                    NULL);

  save_indicator =
    XtVaCreateManagedWidget("save_indicator",
                    xmDrawnButtonWidgetClass,
                    main_w,
                    XmNrecomputeSize, false,
                    XmNpushButtonEnabled, false,
                    XmNshadowType, XmSHADOW_IN,
                    XmNwidth, 120,
                    XmNheight, 31,
                    XmNmarginBottom, 13,
                    XmNlabelType, XmSTRING,
                    NULL);
  XtAddCallback(save_indicator, XmNactivateCallback,
save_indicator_cb,NULL);

  error_indicator =
    XtVaCreateManagedWidget("error_indicator",
                    xmDrawnButtonWidgetClass,
                    main_w,
                    XmNrecomputeSize, false,
                    XmNpushButtonEnabled, false,
                    XmNshadowType, XmSHADOW_IN,
                    XmNwidth, 120,
                    XmNheight, 31,
                    XmNmarginBottom, 13,
                    XmNlabelType, XmSTRING,
                    NULL);
  XtAddCallback(error_indicator, XmNactivateCallback,
          error_indicator_cb, NULL);

  drawing_a =
    XtVaCreateManagedWidget("drawing_a",
                    xmDrawingAreaWidgetClass, scrolled_win,
                    XmNunitType, Xm1000TH_INCHES,
                    XmNwidth, 11000,
                    XmNheight, 8500,
                    XmNresizePolicy, XmNONE,
                    NULL);
  XtAddCallback(drawing_a, XmNexposeCallback, redraw, NULL);

  XtVaSetValues(drawing_a, XmNunitType, XmPIXELS, NULL);
  XmProcessTraversal(drawing_a, XmTRAVERSE_CURRENT);
  XtVaGetValues(drawing_a, XmNwidth, &width, XmNheight, &height,
              NULL);
```

```
drawing_area_pixmap = XCreatePixmap(display_ptr,
                            root_window, width, height,
                            DefaultDepthOfScreen(screen_ptr));
XFillRectangle(display_ptr, drawing_area_pixmap,
               erase_context, 0, 0, width, height);

XtVaSetValues(drawing_a,  XmNtranslations,
          XtParseTranslationTable(translations), NULL);

XtVaSetValues(rowcol,
          XmNtopAttachment,     XmATTACH_FORM,
          XmNrightAttachment,   XmATTACH_NONE,
          XmNleftAttachment,    XmATTACH_FORM,
          XmNbottomAttachment,  XmATTACH_WIDGET,
          XmNbottomWidget,      save_indicator,
          NULL);

XtVaSetValues(menubar,
          XmNtopAttachment,     XmATTACH_FORM,
          XmNrightAttachment,   XmATTACH_FORM,
          XmNleftAttachment,    XmATTACH_WIDGET,
          XmNleftWidget,        rowcol,
          XmNbottomAttachment,  XmATTACH_NONE,
          NULL);

XtVaSetValues(current_op_name,
          XmNtopAttachment,     XmATTACH_WIDGET,
          XmNtopWidget,         menubar,
          XmNrightAttachment,   XmATTACH_WIDGET,
          XmNrightWidget,       current_op_met,
          XmNleftAttachment,    XmATTACH_WIDGET,
          XmNleftWidget,        rowcol,
          XmNbottomAttachment,  XmATTACH_NONE,
          NULL);

XtVaSetValues(current_op_met,
          XmNtopAttachment,     XmATTACH_WIDGET,
          XmNtopWidget,         menubar,
          XmNrightAttachment,   XmATTACH_FORM,
          XmNleftAttachment,    XmATTACH_NONE,
          XmNbottomAttachment,  XmATTACH_NONE,
          NULL);

XtVaSetValues(scrolled_win,
          XmNtopAttachment,     XmATTACH_WIDGET,
          XmNtopWidget,         current_op_name,
          XmNrightAttachment,   XmATTACH_FORM,
          XmNleftAttachment,    XmATTACH_WIDGET,
          XmNleftWidget,        rowcol,
          XmNbottomAttachment,  XmATTACH_WIDGET,
          XmNbottomWidget,      status_indicator,
          NULL);

XtVaSetValues(save_indicator,
          XmNtopAttachment,     XmATTACH_NONE,
          XmNrightAttachment,   XmATTACH_NONE,
          XmNleftAttachment,    XmATTACH_FORM,
          XmNbottomAttachment,  XmATTACH_FORM,
          NULL);

XtVaSetValues(error_indicator,
```

```
            XmNtopAttachment,     XmATTACH_NONE,
            XmNrightAttachment,   XmATTACH_NONE,
            XmNleftAttachment,    XmATTACH_WIDGET,
            XmNleftWidget,        save_indicator,
            XmNbottomAttachment,  XmATTACH_FORM,
            NULL);

  XtVaSetValues(status_indicator,
            XmNtopAttachment,     XmATTACH_NONE,
            XmNrightAttachment,   XmATTACH_FORM,
            XmNleftAttachment,    XmATTACH_WIDGET,
            XmNleftWidget,        error_indicator,
            XmNbottomAttachment,  XmATTACH_FORM,
            NULL);


  XtRealizeWidget(toplevel);
  draw_window = XtWindow(drawing_a);

  graphic_list.set_draw_environ(display_ptr,
                        std_graphics_context,
                        erase_context, dotted_context,
                        draw_window,
                        &drawing_area_pixmap,
                        color_table,
                        width, height);
  graphic_list.set_error_tgt(drawing_a);

  set_current_op();
  set_current_op_met();

  XmProcessTraversal(drawing_a, XmTRAVERSE_CURRENT);

  toplevel_window = XtWindowOfObject(toplevel);
  Atom display_id_atom = XInternAtom(display_ptr, "WINDOW_ID",
                             False);
  XChangeProperty(display_ptr, root_window, display_id_atom,
            XA_WINDOW, 32, PropModeReplace,
            (unsigned char *) &toplevel_window, 1);
  XtAddEventHandler(toplevel, NoEventMask, true, event_handler,
             NULL);

  motif_initialized = true;
}

//   translations provides the mappings for the keyboard
// mapping table that allow the drawing canvas to capture
// mouse and keyboard events.

// The primary function, edit_graph.  Modified from original main() by
// Doug Lange 9/9/96


/*********************************************************************
* this method is added to support the edit graph and sde change over.
* now the edit graph module is not a standalone but a method called
* from the sde
*********************************************************************/

//extern "C" {
```

```
/*
 * modified 7/12/97
 * int edit_graph(...)  -> void  edit_graph(...)
 */

void edit_graph(GRAPH_DESC current_graph, ACTION next_action,
              ERROR_MSGS sde_error_msgs)                         {    //@2

  XEvent event;  // added for custom main loop

  int    reply;
  Quest_Script delete_script  =
          {"","Deleted operators will be purged?", "Ok","No","Cancel",
BTN1};

  next_action_ptr    = next_action;
  errors_present     = sde_error_msgs;
  return_sde_flag = false;

  gdnode = current_graph;

  // motif_initialized assumed to be false at start of procedure

  if (motif_initialized) {
    XFillRectangle(display_ptr, drawing_area_pixmap,
               erase_context, 0, 0, width, height);
    XFillRectangle(display_ptr, draw_window,
               erase_context, 0, 0, width, height);
    if (gdnode) {
      graphic_list.build_from_sde(gdnode);
    }

    if (save_performed)
      save_state(NOT_MODIFIED);
    if (prev_status) {
      update_status(prev_status, false);
      free(prev_status);
      prev_status = NULL;
    }
    graphic_list.draw();
    setcursor(toplevel,True,XC_left_ptr);
  }
  else {
    init_motif();
    prev_status = NULL;
    save_state(NOT_MODIFIED);
    save_performed = false;
    default_color = WHITE;
    default_font  = COURIERBOLD12;
    graphic_list.set_default_font(default_font);
    if (gdnode) {
      graphic_list.build_from_sde(gdnode);
    }

    graphic_list.draw();

    select_state(SELECT_TOOL);

    // Initialize printer command
    PrintCmd.op       = Snd_to_Prt;
    PrintCmd.printer = dup_str("");
```

```
    PrintCmd.file     = dup_str("");
    PrintCmd.answer   = 0;

    // and event
    print_event->type = ClientMessage;
    print_event->xclient.window = toplevel_window;
    print_event->xclient.format = 8;
    strcpy(print_event->xclient.data.b, "PrintWindow");
  }
  set_editor_title();
  set_current_op();
  set_current_op_met();

  syntax_checked = true;     // syntax is checked on each entry to editor
  error_label();

  if (graphic_list.cur_op_is_terminator())
    XtVaSetValues(op_button, XmNsensitive, False, NULL);
  else
    XtVaSetValues(op_button, XmNsensitive, True,  NULL);

  // MY // printf("\n"); //flushes the event queue
  XFlush(display_ptr);

#ifdef GE_DEBUG
      cout << "Starting Motif event loop" << endl;
#endif

  selected_object_ptr = NULL;

  // Custom main loop to check for return to sde
  do {
    XtAppNextEvent(app, &event);
    XtDispatchEvent(&event);

    if (return_sde_flag) {
      if (graphic_list.has_deleted()) {
        reply = AskUser(app, drawing_a, delete_script);
        if (reply != YES)
          return_sde_flag = false;
      }
    }

  } while (return_sde_flag == false);

  if ((next_action->option != REVERT) &&
      (next_action->option != ABANDON))
    graphic_list.write_to_sde(gdnode);

  if ((next_action_ptr->option == SAVE_TO_DISK) ||
      (next_action_ptr->option == REVERT)) // not really saved, but not
    save_performed = true;                 // modified
  else
    save_performed = false;                // assume need to save for
abandon

  // If we are not coming back, kill the window
  if (!next_action_ptr->reinvoke) {
    XtUnrealizeWidget(toplevel);
    XFlush(display_ptr);
  }
```

```
  else {  // otherwise, will be returning, erase window and exit
    setcursor(toplevel,True,XC_watch);
  }
  return;
}

//} // extern "C"

/*************************************************************************
*                    --- end of graph_editor.C
*************************************************************************/
```

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